

**CIPANP 2009: Tenth Conference on the Intersections of  
Particle and Nuclear Physics**

Torrey Pines Hilton—San Diego, California—26 May to 31 May, 2009

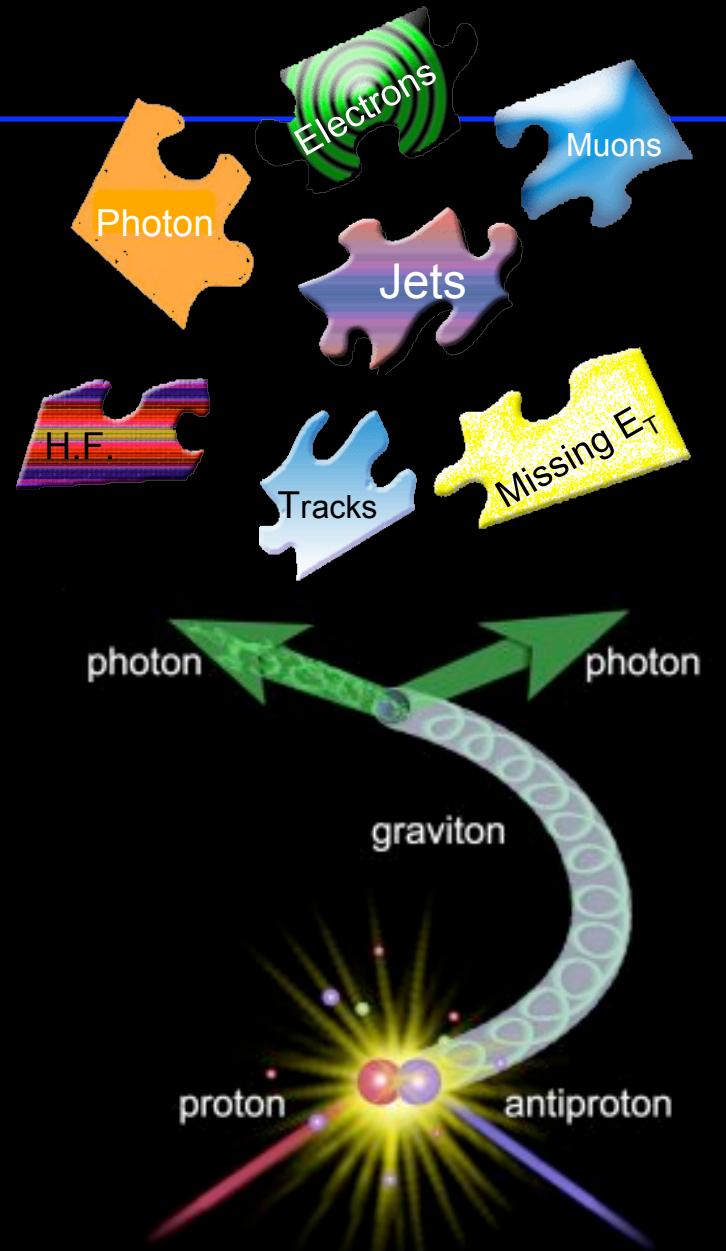
# *Search for New Physics at the Tevatron*

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*(on behalf of the CDF and DØ Collaborations)*

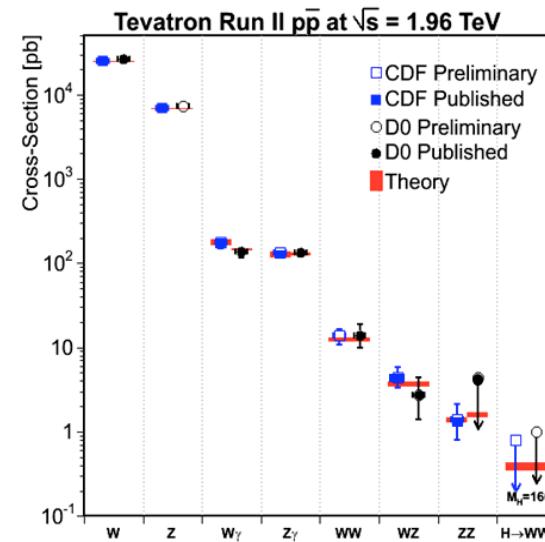
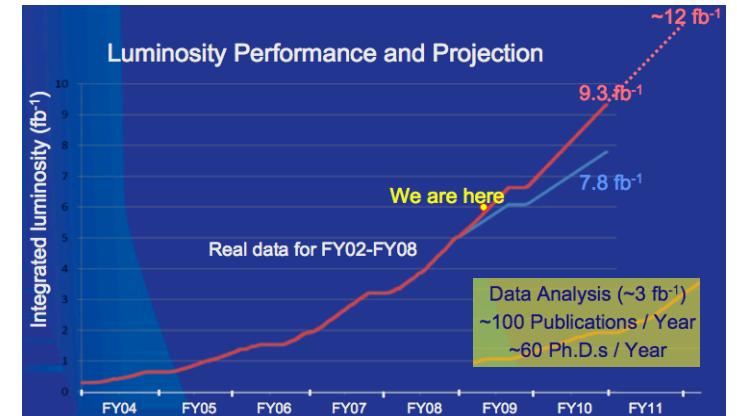
# Outline of the talk

- TeVatron status
- Signature-based searches
  - from simple objects to complex final states
    - leptons-only final states (and isolated tracks)
    - ... + Missing Energy and Photons
    - ... + Jets and heavy flavors
  - Search for SUSY
- Final remarks and conclusions



# Tevatron Status

- The TeVatron is currently the highest energy running collider in the world
  - ppbar collider, located about 30 miles west of Chicago, IL
    - 1.96 TeV in the C.M.
  - Data are accumulated at fast rate continuously
  - The machine and the detectors (CDF and D0) are performing very well
    - systematic uncertainties are very well under control
    - Measurements are becoming very precise
      - Top quark mass known with precision < 2%
    - New analyses are now looking for the needle in the haystack
      - low cross section phenomena



# Signatures and Physics Objects

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Many processes: several signatures

## Leptons-only final states

- e/ $\mu$  identification well understood
- $\tau$  id a little more complex
- Straightforward and highly efficient approach to search for anomalies

## .... + Missing Energy and Photons

- Wealth of models and exotic processes
- Need accurate understanding of detector effects

## .... + Jets and heavy flavors

- More complex signatures
- Maintaining high S/ $\sqrt{B}$

When a signature-based approach is advocated, final results are generally interpreted in terms of specific models (typical case dilepton searches, MET + jets)

When the analysis is model driven and results are presented as testing of a specific model, there is always a check on control regions, defined in terms of the process signature (blind analyses)

The two approaches are usually pursued in a balanced and complementary way

# Signature-based searches

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Open searches, final states are analyzed for anomalies when compared with the SM

- Mass bumps searches
- Multi-objects final state (low background)
- Global Searches

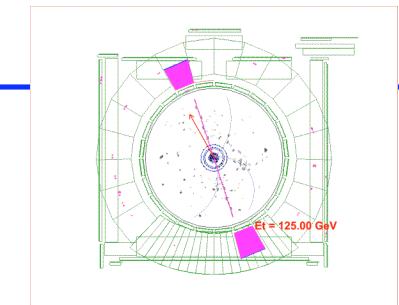
Identification efficiency, detector effects and systematic uncertainties need to be very well understood.

The analysis might not be optimized for the latest theory model available but it might be general enough to exclude several other models.

# Dilepton final states

Old-fashioned mass bump hunt..

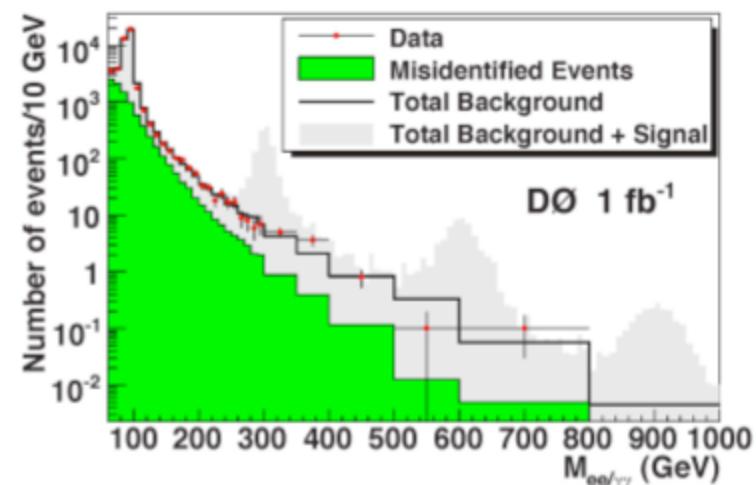
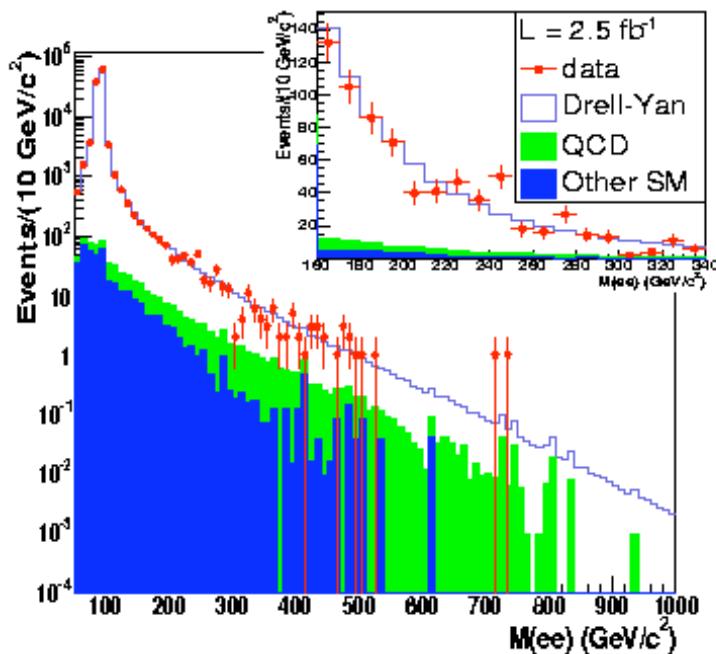
- Z production and decay into ee/ $\mu\mu$  precisely measured
- Lepton ID/Reco and Trigger efficiencies high and very well understood
- Background low and easily determined (QCD fakes)
- Clean events



The most significant region of excess for an  $e^+e^-$  invariant mass window of 240  $\text{GeV}/c^2$  (CDF)

3.8 standard deviations above the SM prediction

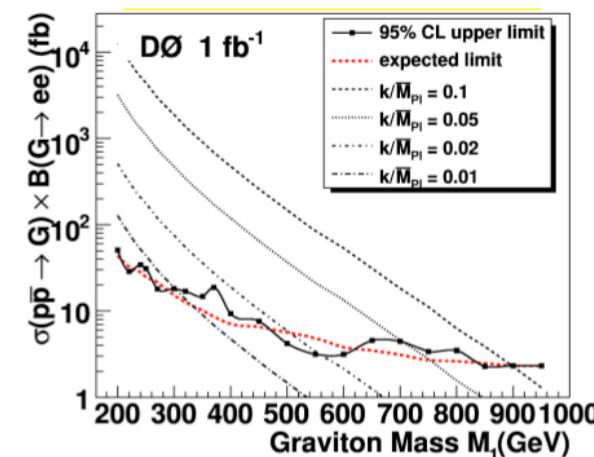
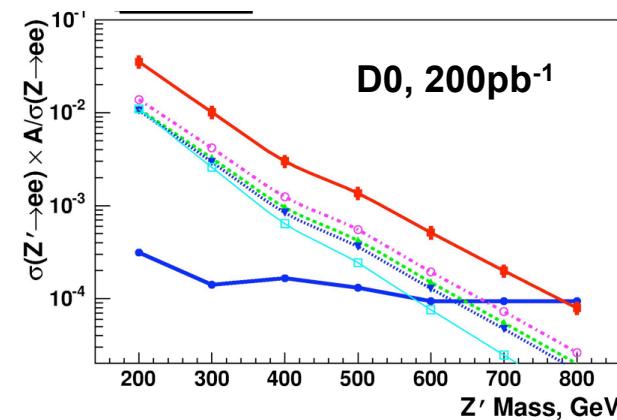
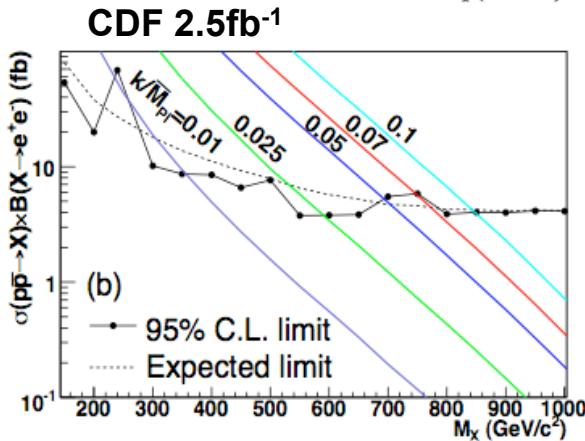
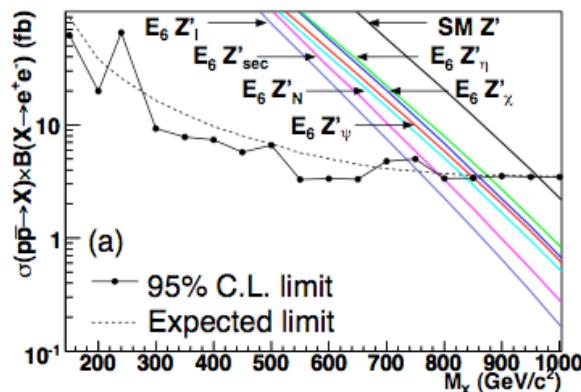
Excess is monitored (data period) Cross-check in muons  
D0 does not see any deviation from SM



# Testing different models

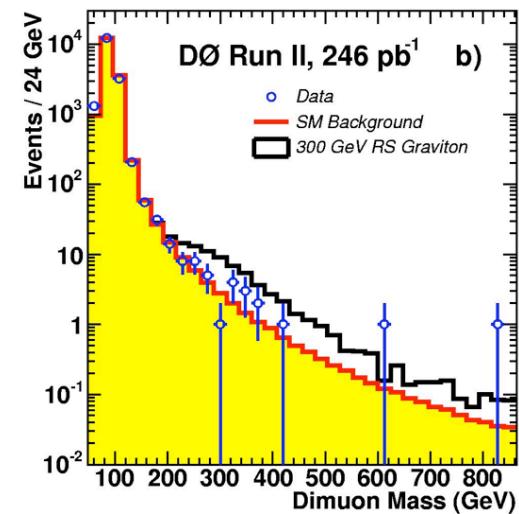
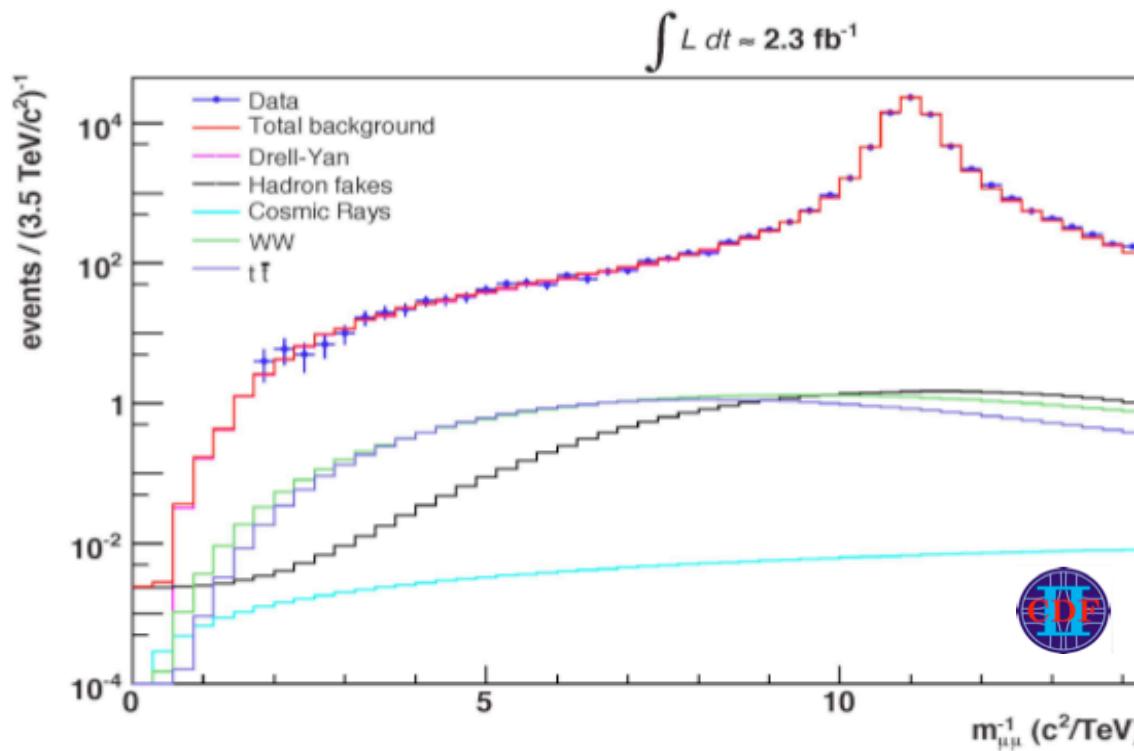
Once the data spectrum is well understood in terms of SM background, from MC, the acceptances for resonant states for different spin particles are derived (Z', RS Graviton) and the expected number of BSM events is calculated.

In the absence of an excess of data, 95% CL limits on production cross-sections and mass of the particles are set.



# Z' searches in dimuons

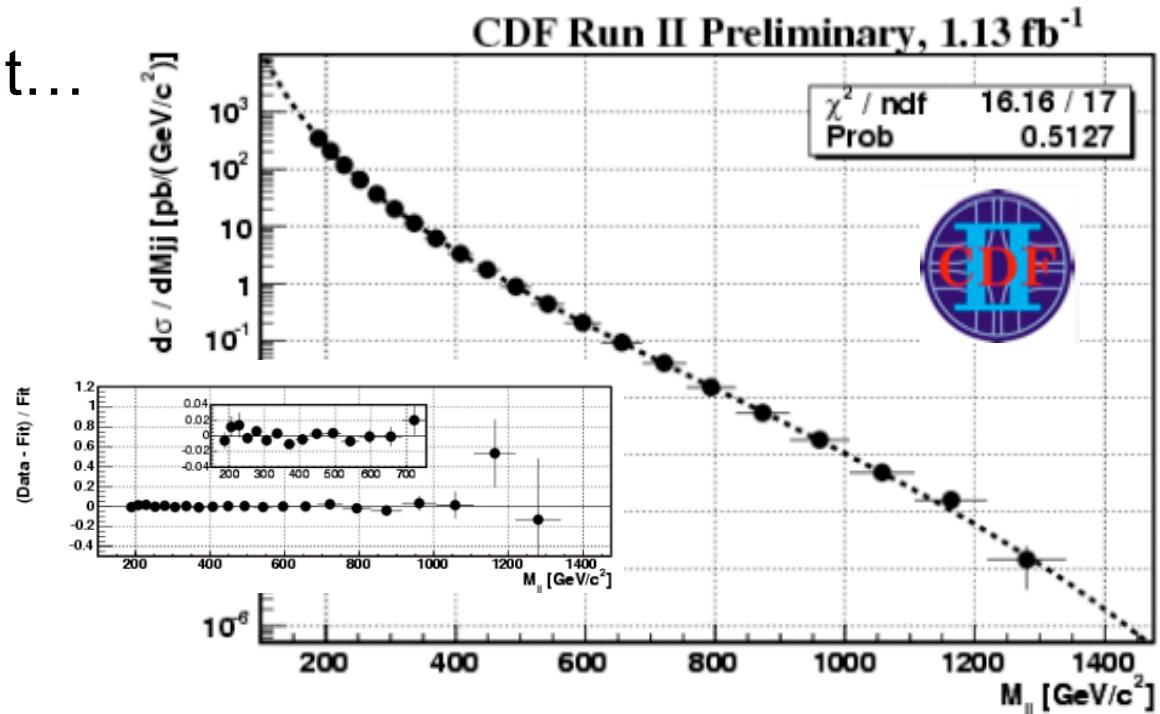
CDF has a new result out searching for bump in the  $X \rightarrow \mu\mu$  final state: no excess is observed.



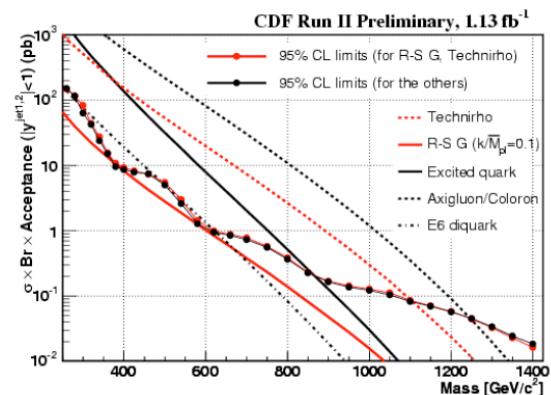
# Dijets final state

Another mass bump hunt...

- ◆ Choose events with two high- $p_T$  jets with rapidity less than 1.0. Look for an excess in the dijet mass spectrum for masses above 180 GeV
- ◆ Possible signals include excited quarks,  $W'$ ,  $Z'$ , and Randall-Sundrum gravitons
- ◆ Find functional form of dijet spectrum in pythia and herwig, fit to data. Look for “bumps” in the data minus fit plot



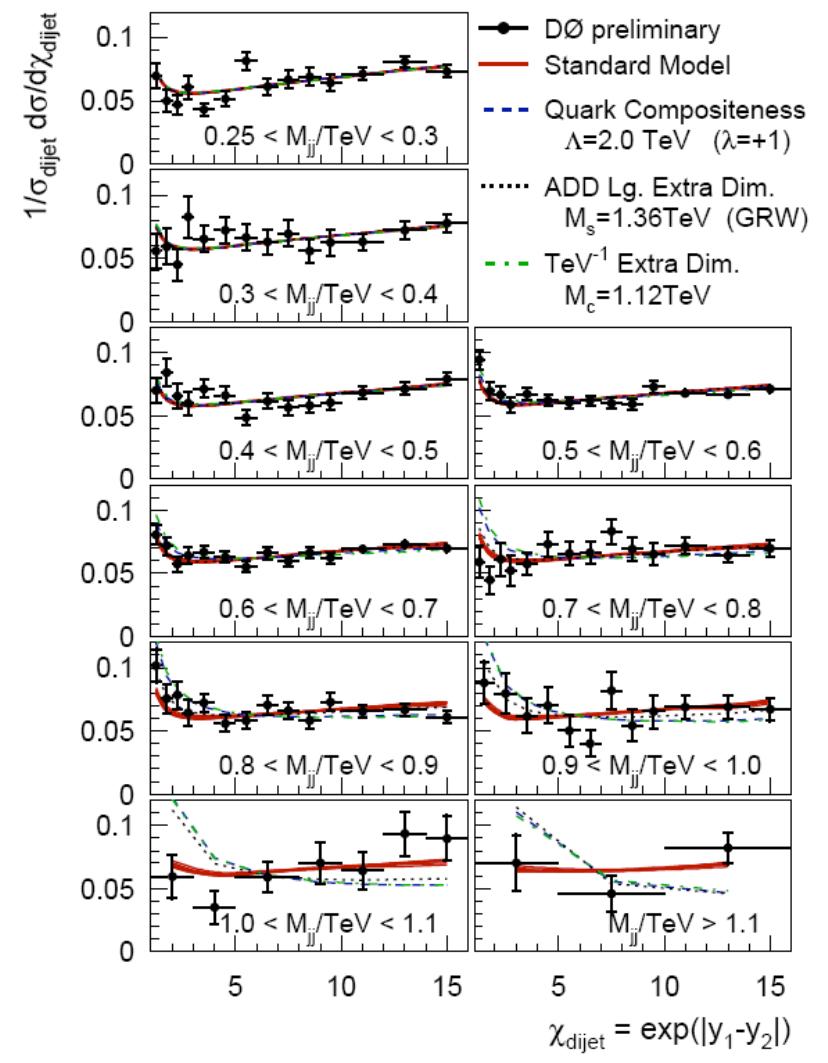
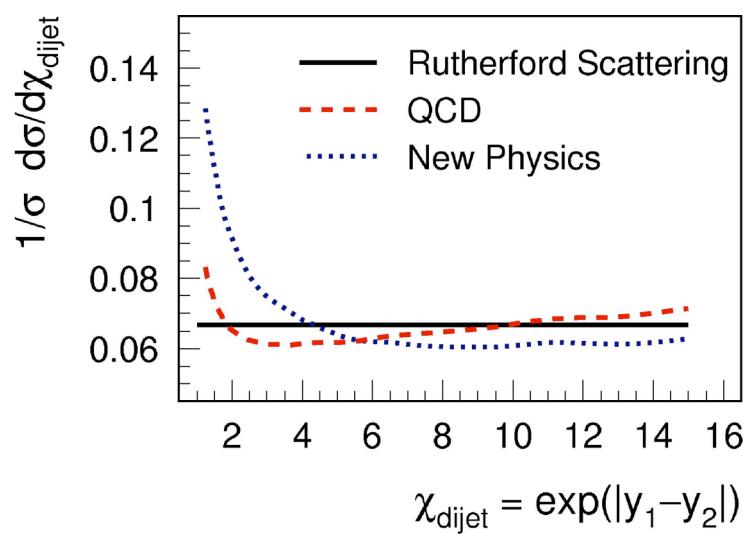
- ◆ No significant resonant structure is observed, so limits are set on various models
- ◆ Excludes (at 95% CL) excited quarks from 260-870 GeV,  $W'$  from 280-840 GeV, and  $Z'$  from 320-740 GeV



# Dijets angular distribution

Dijet angular distributions is measured in bins of dijet mass:

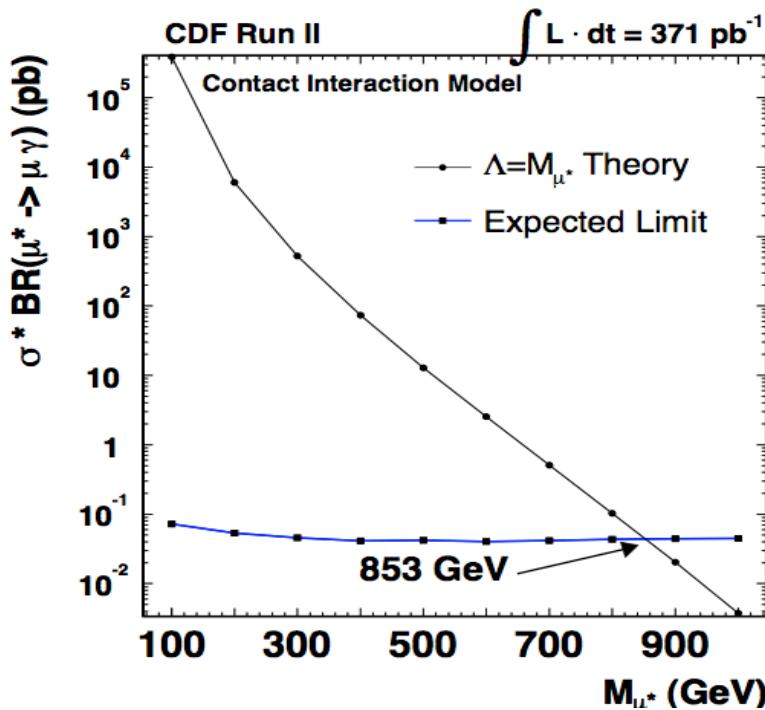
- First differential cross section measurement at partonic energies  $>1$  TeV!
- Small experimental and theoretical uncertainties.
- Sensitive to New Physics (95% CL limits):



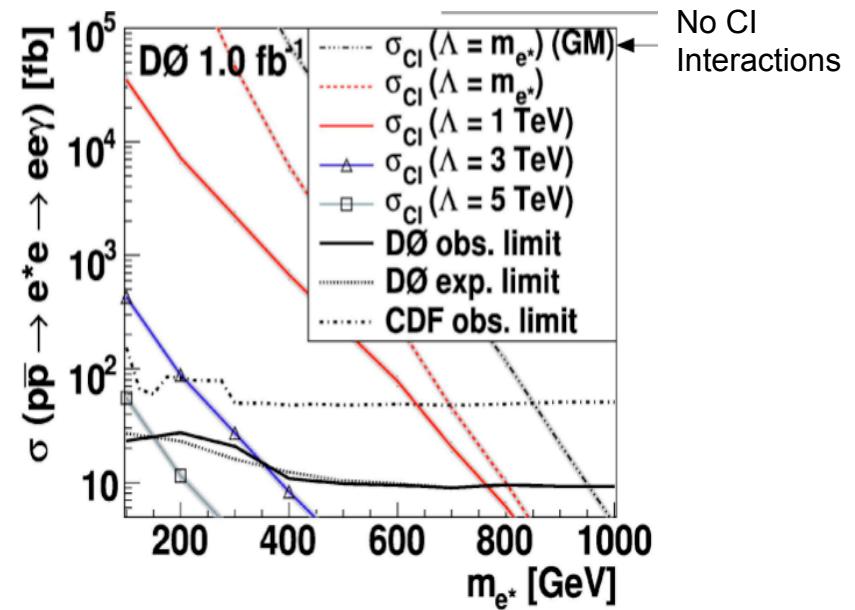
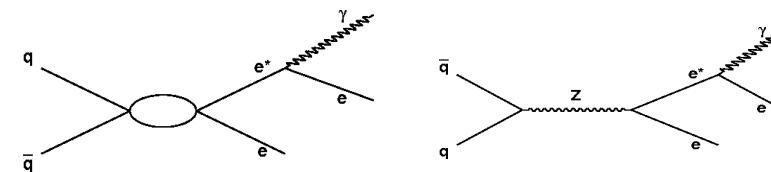
# Lepton+ $\gamma$ final states: Excited leptons

Observation of excited states of quarks and leptons might confirm the hypothesis that they are not elementary particles , but composite states

Select events with eey ( $\mu\mu\gamma$ ) in the final state and look for resonance in  $M(e\gamma)$  or  $M(\mu\gamma)$



At Tevatron,  $e^*/\mu^*$  can be produced via contact interactions or gauge mediated interactions



# Diboson resonance searches: $Z\gamma$

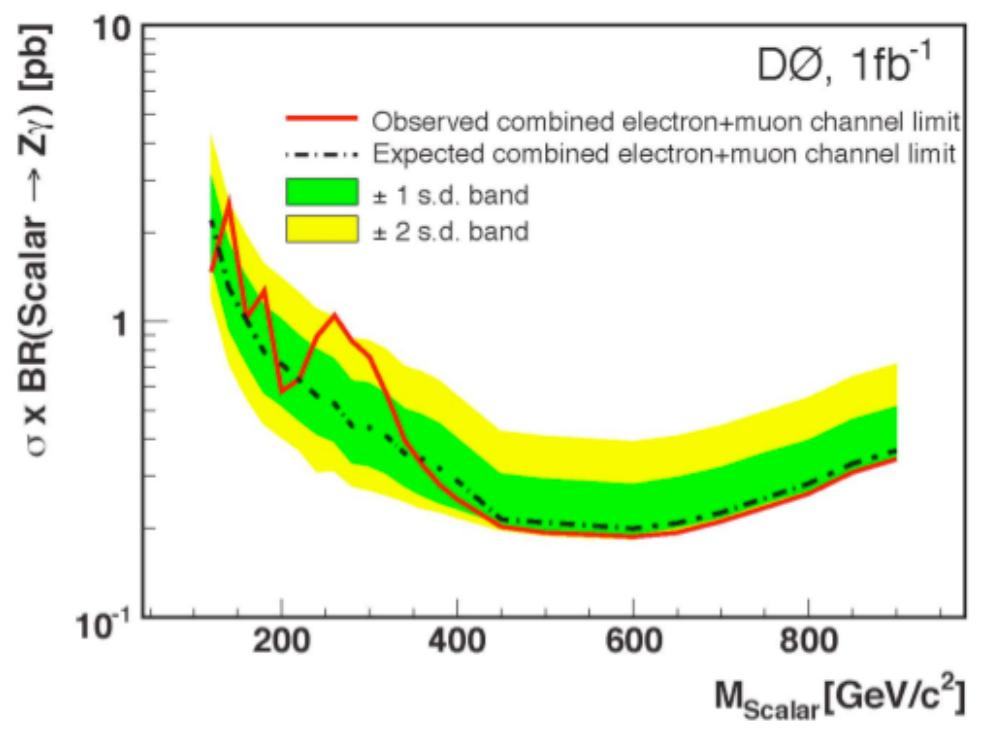
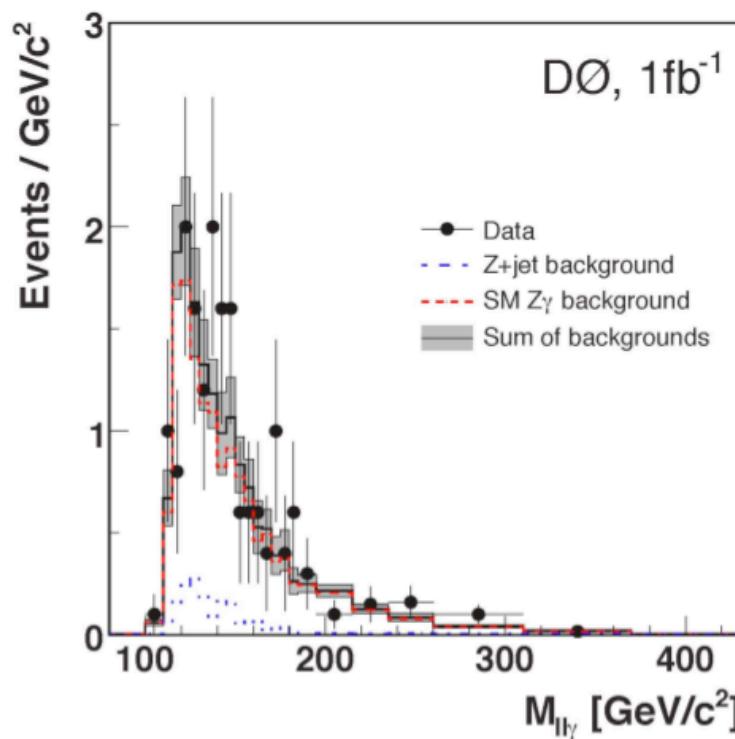


DØ ( $X \rightarrow Z\gamma \rightarrow ee/\mu\mu \gamma$ ): no significant excess

## Scalar [Vector] X

$\sigma \cdot \text{Br}(X \rightarrow Z\gamma) < 0.19[0.20] \text{ pb } (M_X = 600 \text{ GeV})$

$< 2.5[3.1] \text{ pb } (M_X = 140 \text{ GeV})$



# Diboson resonance searches: WW/WZ

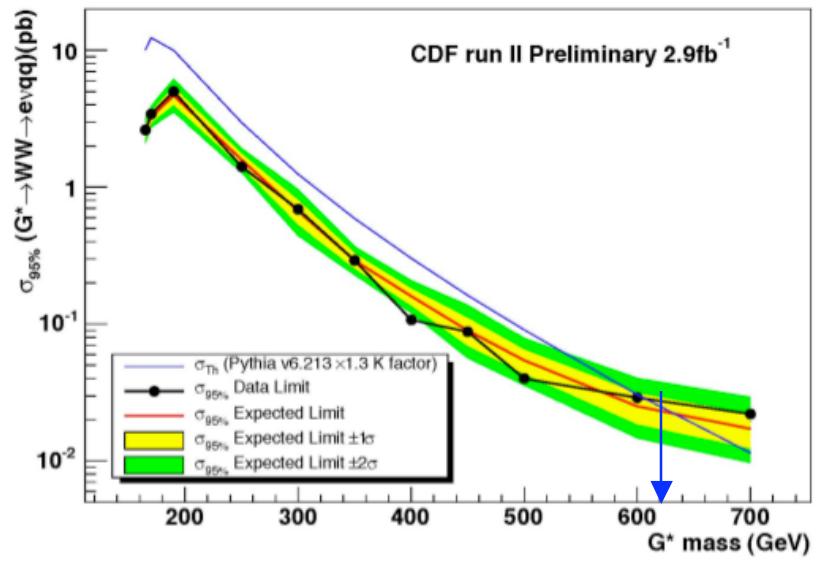
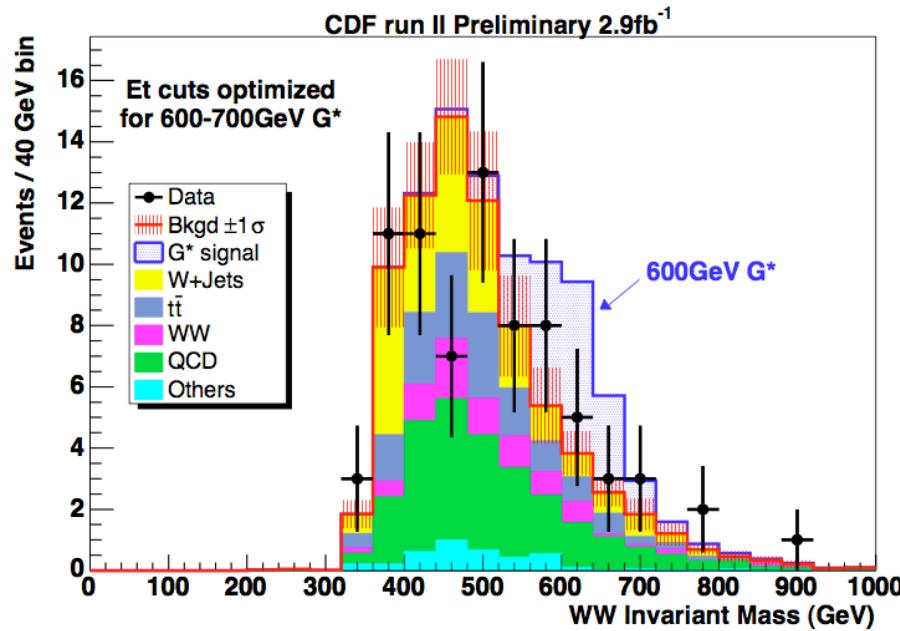


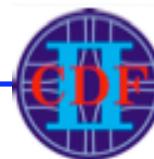
CDF ( $X \rightarrow WW/WZ \rightarrow e\nu jj$ ): no significant excess  
 $\Rightarrow$  set limits on  $W'$ ,  $Z'$ , RS graviton

$$M_{W'} \notin (284, 515) \text{ GeV}$$

$$M_{Z'} \notin (247, 545) \text{ GeV}$$

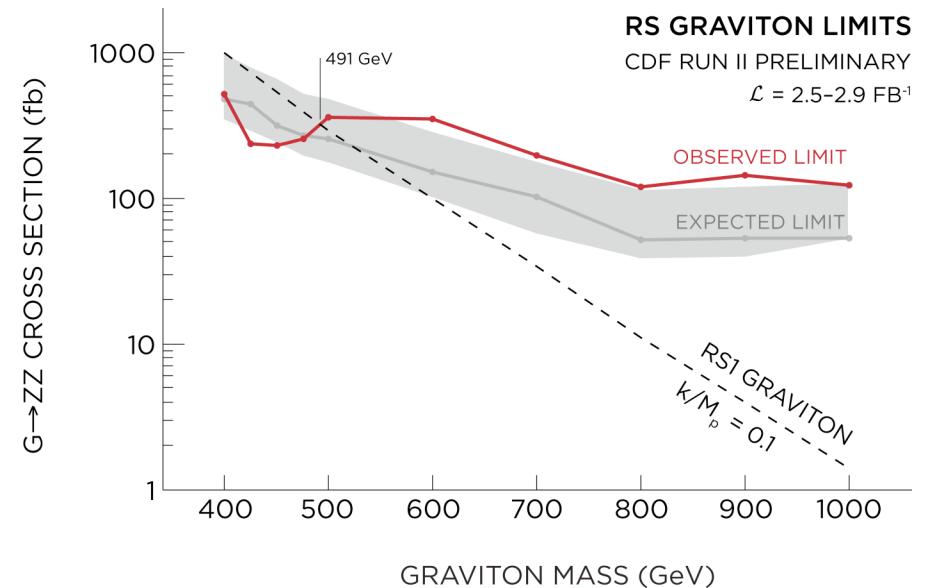
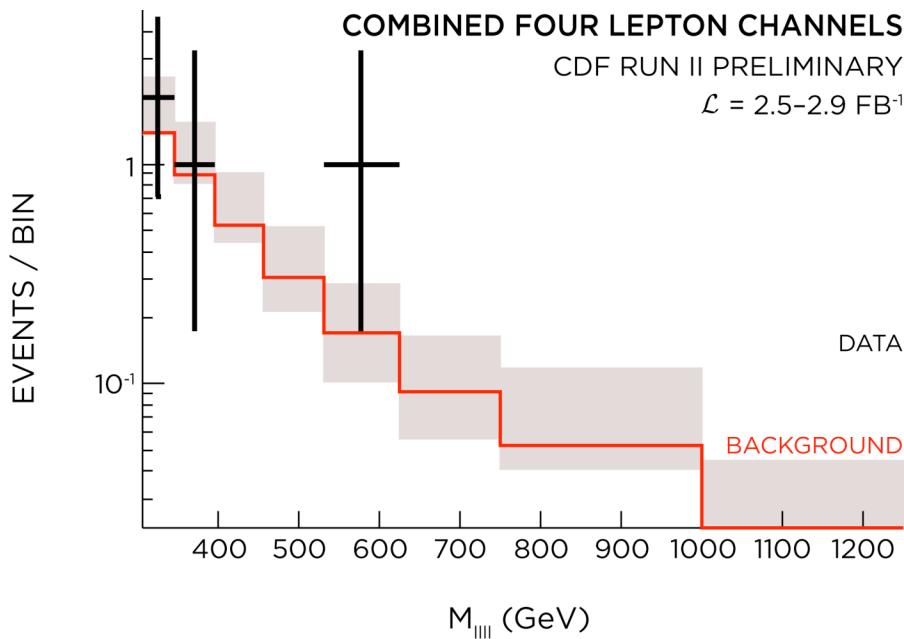
$$M_G > 607 \text{ GeV} (k/M_p = 0.1)$$





# Diboson resonance searches: ZZ

CDF ( $X \rightarrow ZZ \rightarrow llll, lljj$ ;  $l = e, \mu$ ):  
 newly-improved forward track reconstruction  
 more efficient muon identification  
 no significant excess

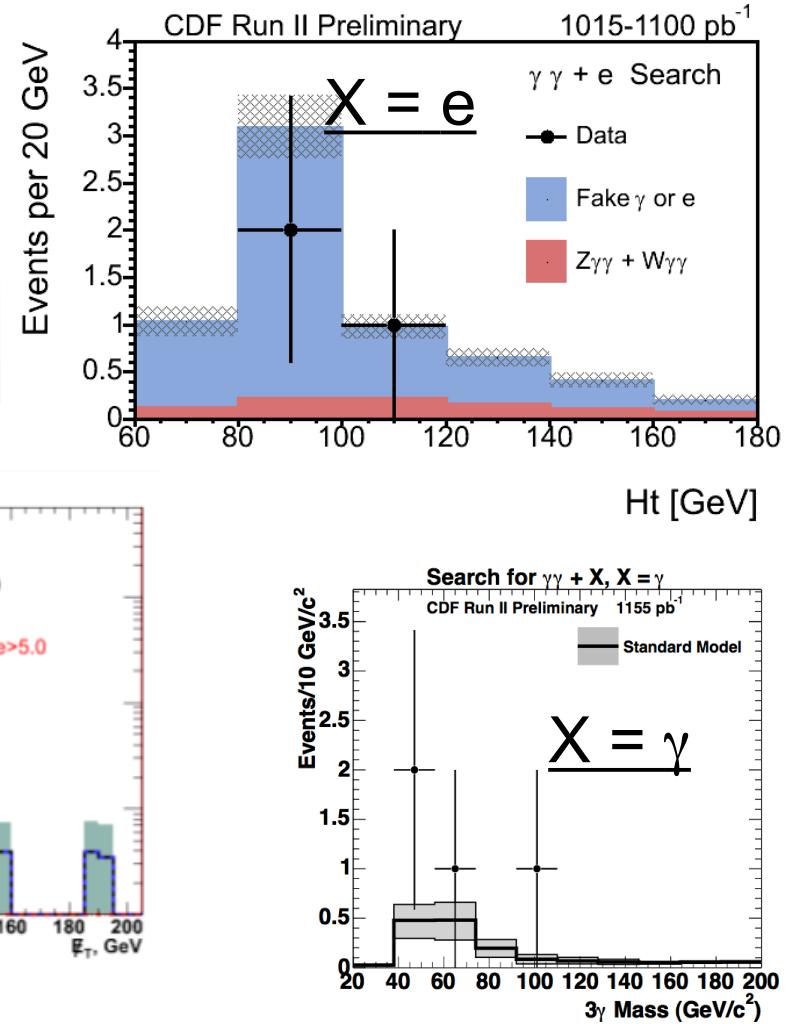
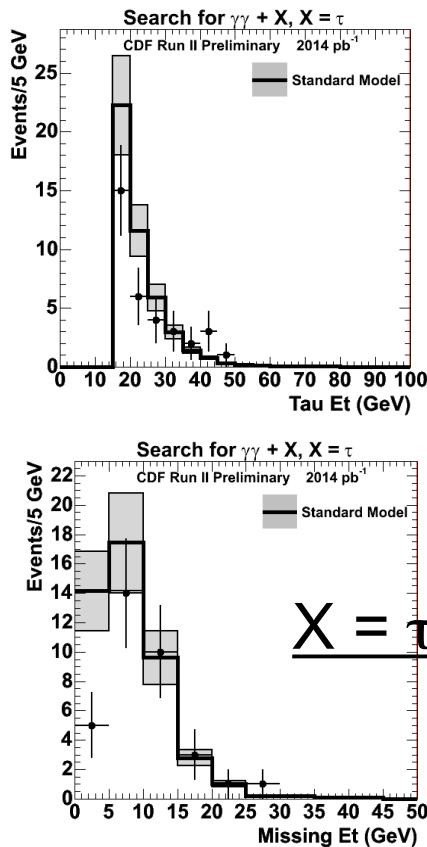


**RS (spin 2)  $G \rightarrow ZZ$**   
 $M > 491 \text{ GeV}$  ( $2.5-2.9 \text{ fb}^{-1}$ ,  $k/M_p = 0.1$ )

# Diphoton+X

Nominal high  $E_T$  object identification and kinematic selections are used.

The observed event counts is reported as well as SM prediction for various kinematic distributions

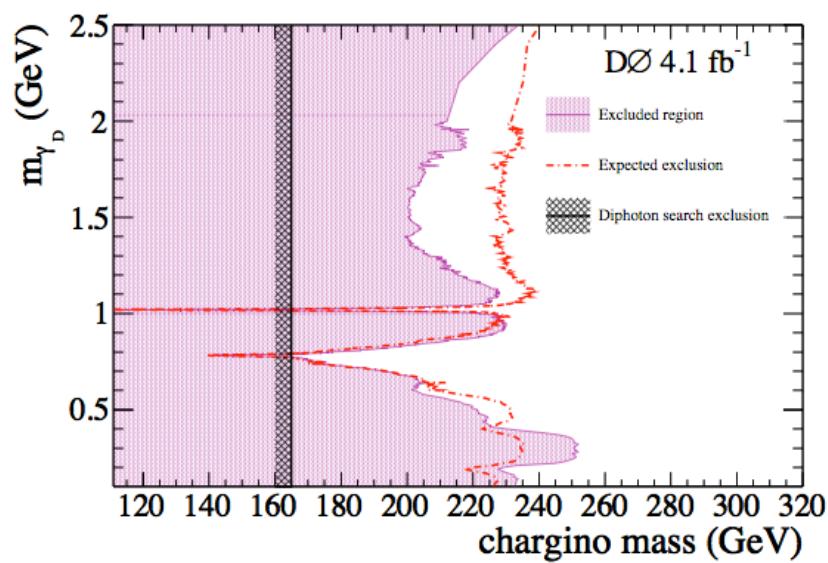
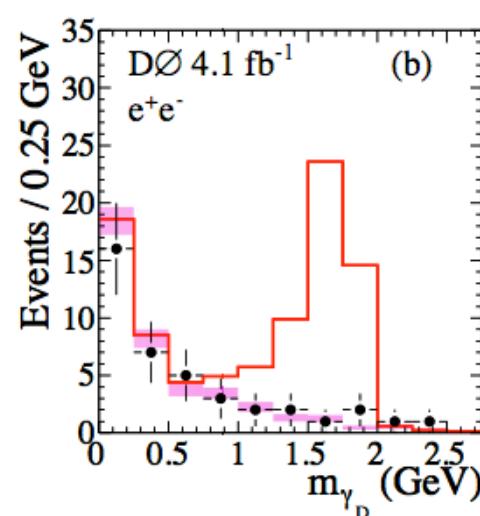
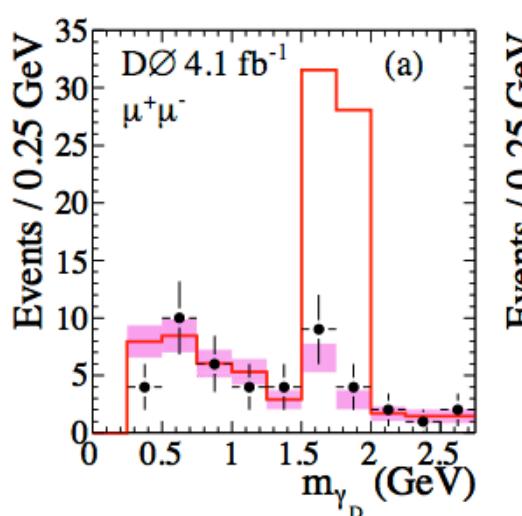
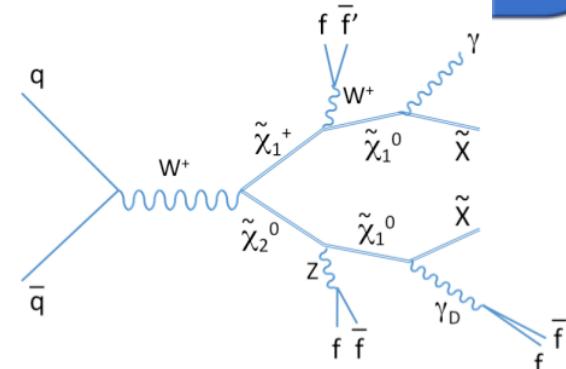


Good agreement between data and SM predictions

# $\gamma + \text{MET} + \text{ll}$

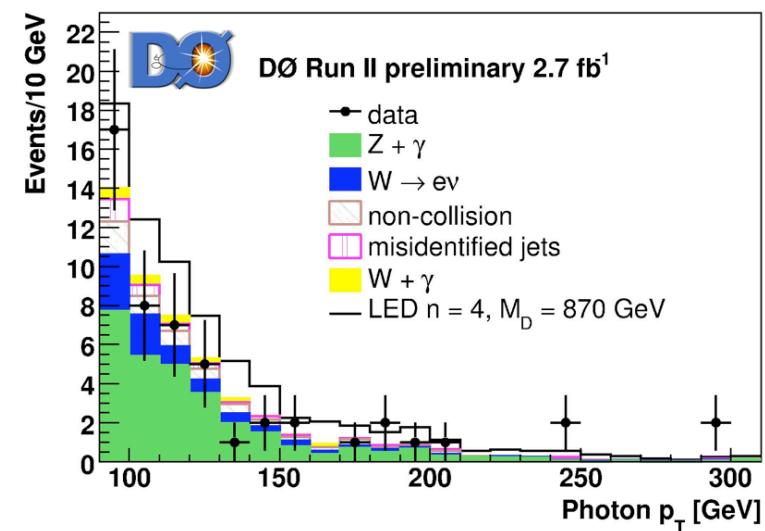
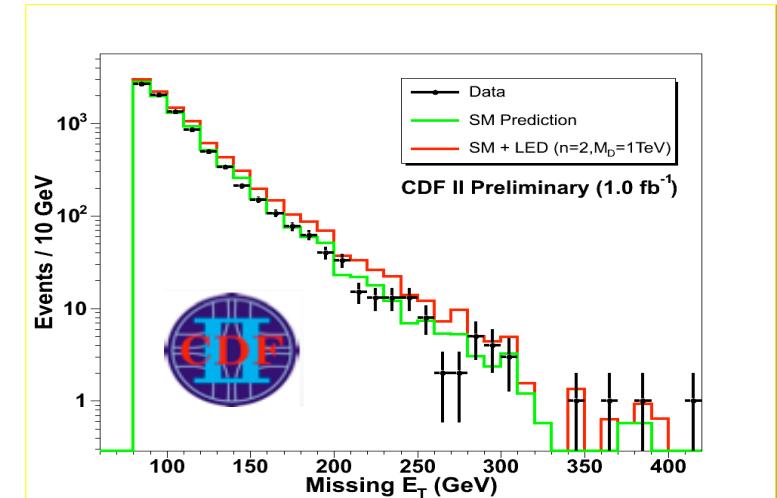
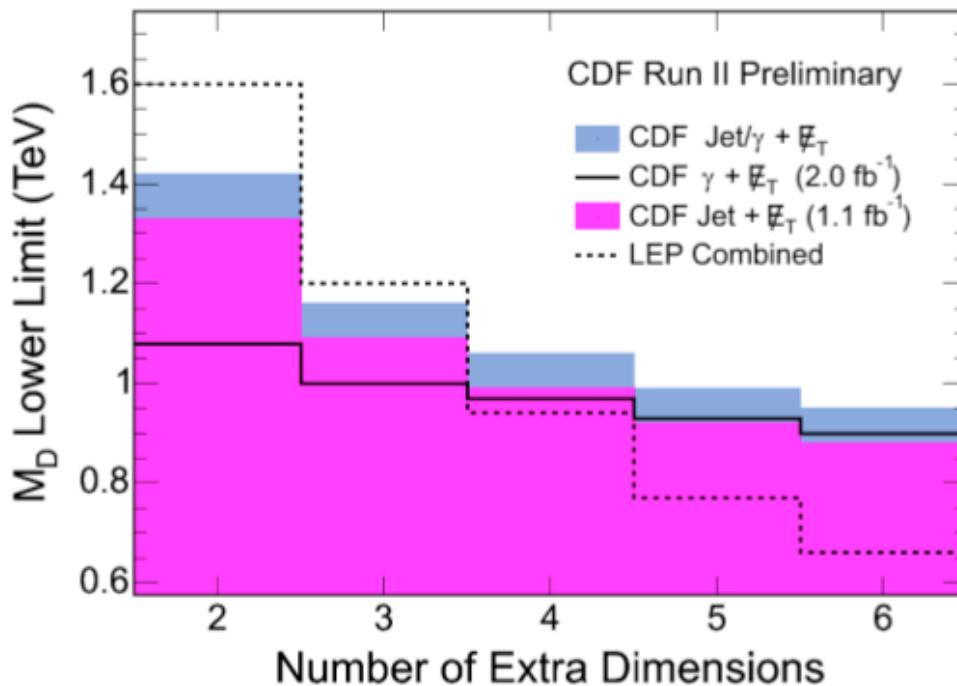
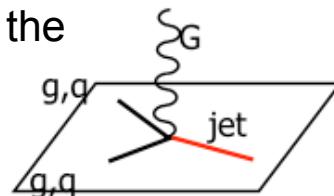


- Very exotic SUSY models :
  - hidden valley dark photons..
  - Axions decaying into muons
  - Hidden-state Y cascading to dark photons
- Signature: Two spatially closed leptons (no Iso), MET and  $\gamma$

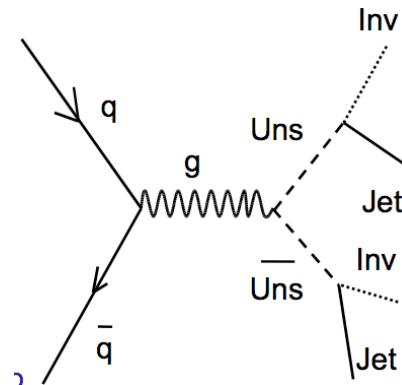


# Single jet/photon + MET: LED

A Kaluza-Klein graviton is produced in association with a jet (or photon). The graviton escapes detection, leaving a monojet (monophoton) signature in the detector



# Jets+MET final state:Leptoquarks



The analysis is a counting experiment examining two different kinematic regions (each region being more sensitive to different models). Cuts are not optimized for a specific model.

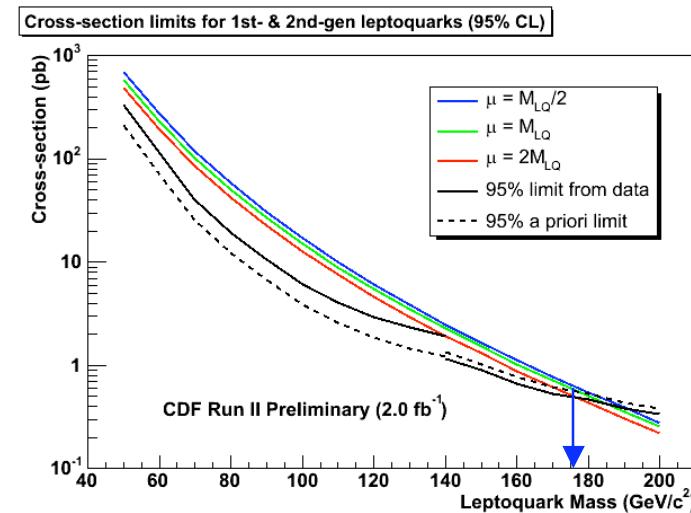
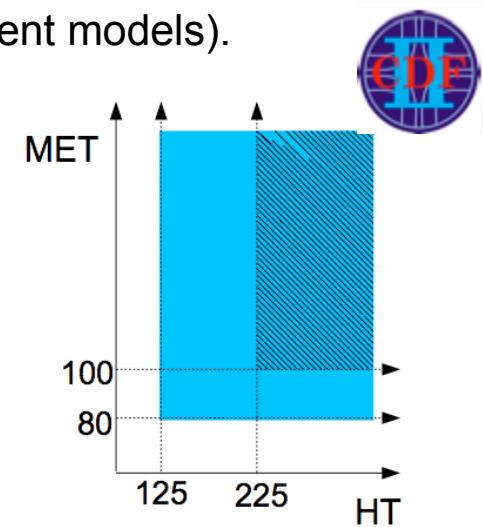
## Main backgrounds:

- $Z \rightarrow \nu \bar{\nu} + \text{jets}$  (irreducible background)
- $W \rightarrow l \nu + \text{jets}$  (with charged lepton lost)
- Residual QCD and non-collision backgrounds.

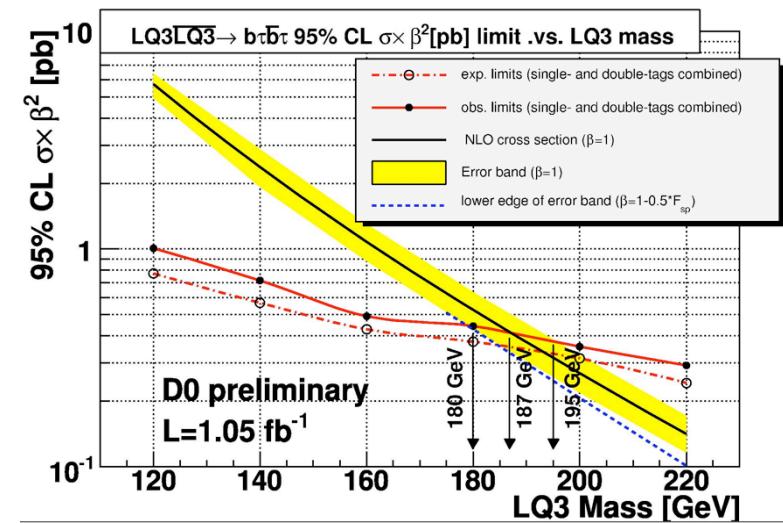
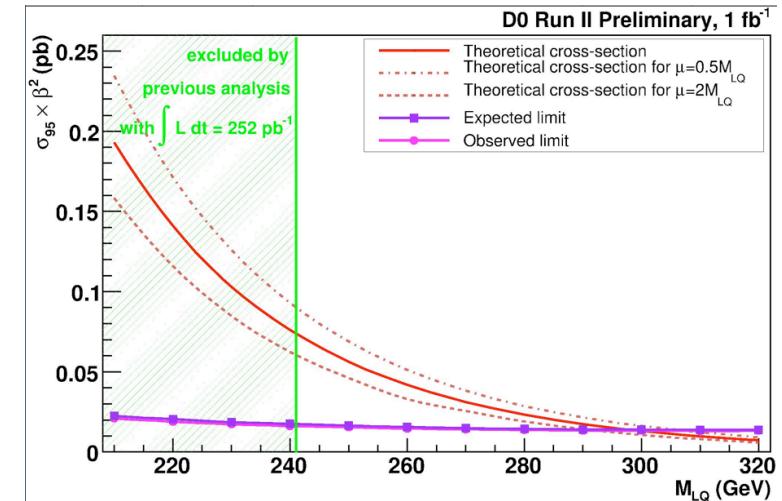
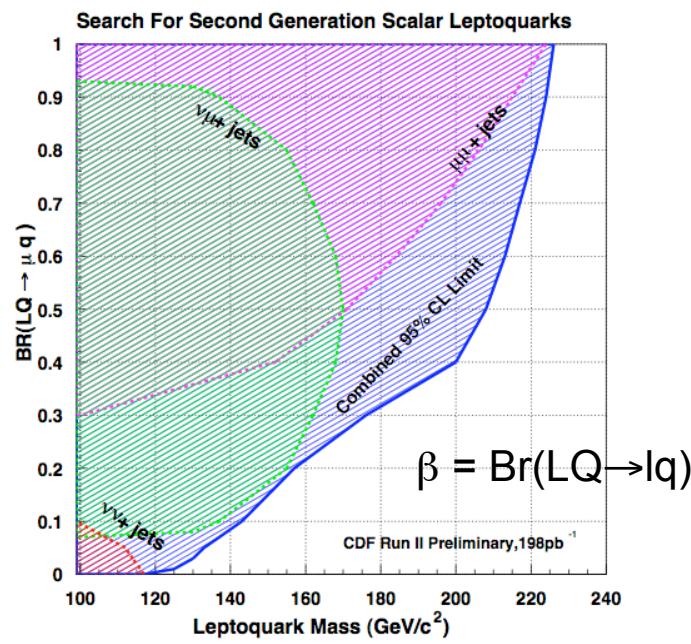
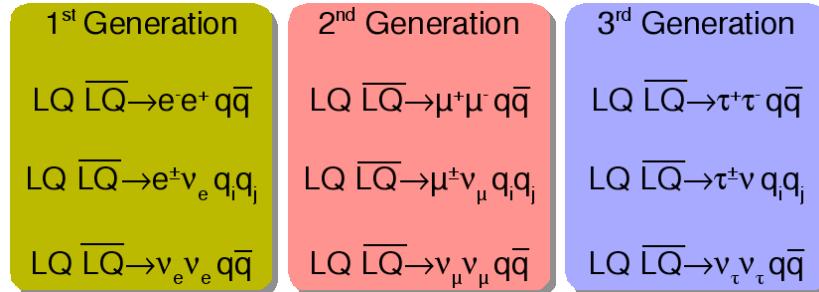
## Data driven prediction

CDF Run II Preliminary,  $2\text{fb}^{-1}$

Background	125/80	225/100
$Z \rightarrow \nu \bar{\nu}$	$777 \pm 49$	$71 \pm 12$
$W \rightarrow \tau \nu$	$669 \pm 42$	$50 \pm 8$
$W \rightarrow \mu \nu$	$399 \pm 25$	$33 \pm 5$
$W \rightarrow e \nu$	$256 \pm 16$	$14 \pm 2$
$Z \rightarrow ll$	$29 \pm 4$	$2 \pm 0$
QCD	$49 \pm 30$	$9 \pm 9$
$\gamma + \text{jets}$	$55 \pm 13$	$5 \pm 3$
top	$74 \pm 9$	$11 \pm 2$
non-collision	$4 \pm 4$	$1 \pm 1$
Total	$2312 \pm 140$	$196 \pm 29$
Observed	<b><math>2506</math></b>	<b><math>186</math></b>

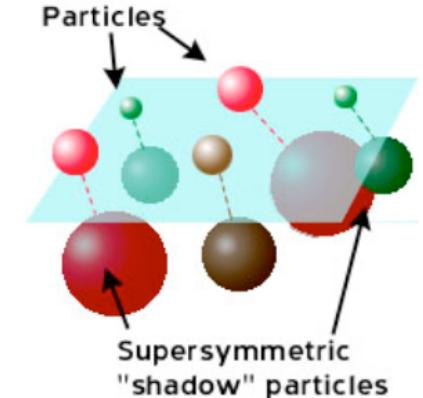
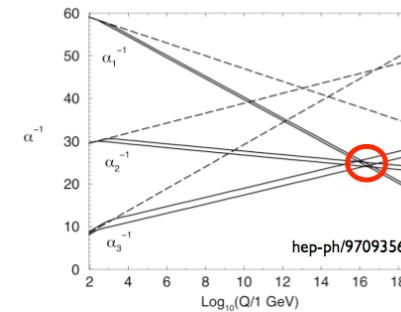


# Other Leptoquarks Results



# Search for Supersymmetry

- SUSY is a very popular extension of the SM...
  - It solves several open issues and provide an elegant description of bosons and fermions



- On the other hand...
  - Full set of new particles with constraints on their masses (TeV scale)
- Various signatures with access to a wide phase space
  - Multileptons final states
  - Jets and MET
  - MET and  $\gamma$
  - Heavy flavors

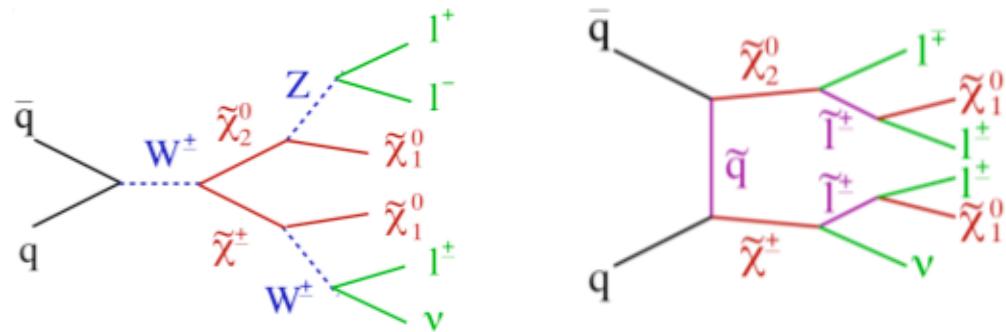
Names	spin	$R_P$	Gauge eigenstates	Mass eigenstates
Higgs bosons	0	+1	$H_u^0 H_d^0 H_u^+ H_d^-$	$h^0 H^0 A^0 H^\pm$
squarks	0	-1	$\tilde{u}_L \tilde{u}_R \tilde{d}_L \tilde{d}_R$ $\tilde{c}_L \tilde{c}_R \tilde{s}_L \tilde{s}_R$ $\tilde{t}_L \tilde{t}_R \tilde{b}_L \tilde{b}_R$	same same $\tilde{t}_1 \tilde{t}_2 \tilde{b}_1 \tilde{b}_2$
sleptons	0	-1	$\tilde{e}_L \tilde{e}_R \tilde{\nu}_e$ $\tilde{\mu}_L \tilde{\mu}_R \tilde{\nu}_\mu$ $\tilde{\tau}_L \tilde{\tau}_R \tilde{\nu}_\tau$	same same $\tilde{\tau}_1 \tilde{\tau}_2 \tilde{\nu}_\tau$
neutralinos	1/2	-1	$\tilde{B}^0 \tilde{W}^0 \tilde{H}_u^0 \tilde{H}_d^0$	$\chi_1^0 \chi_2^0 \chi_3^0 \chi_4^0$
charginos	1/2	-1	$\tilde{W}^\pm \tilde{H}_u^+ \tilde{H}_d^-$	$\chi_1^\pm \chi_2^\pm$
gluino	1/2	-1	$\tilde{g}$	same
goldstino	1/2	-1	$\tilde{G}$	same

MSSM particle spectrum

# SUSY in Trileptons

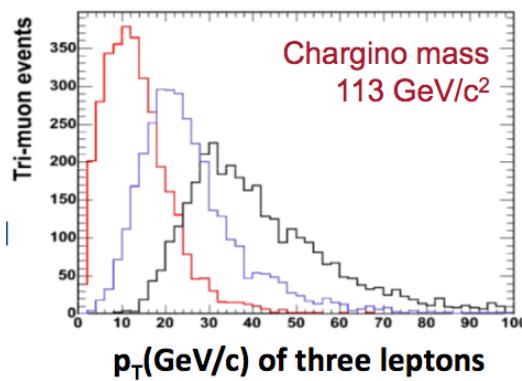
## Very clean signature:

- 3 isolated leptons
- $E_T$  due to undetected  $\tilde{\chi}_1^0$  and  $\nu$



## Challenge:

- low cross section:  
 $\sigma \times Br < 0.5 \text{ pb}$
- very soft 3<sup>rd</sup> lepton p<sub>T</sub>



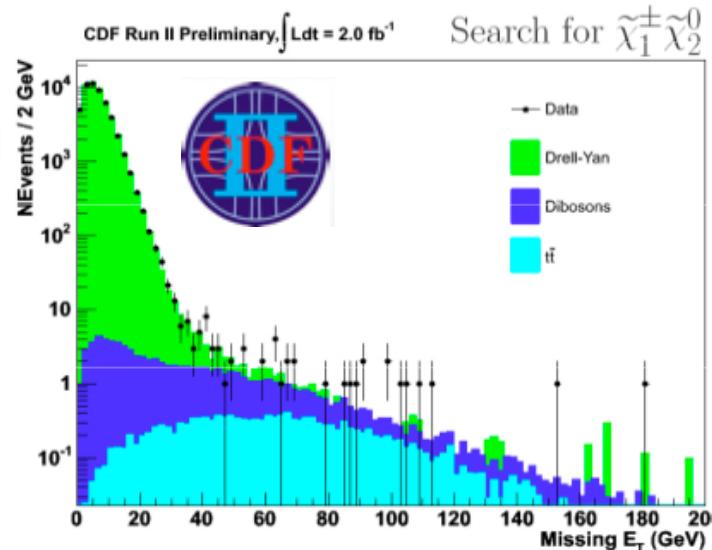
## Search Strategies

- |                                      |   |
|--------------------------------------|---|
| <b>CDF:</b><br>$2.0 \text{ fb}^{-1}$ | <ul style="list-style-type: none"> <li>• 3 identified leptons (e, <math>\mu</math>)</li> <li>• 2 identified leptons + track (<math>\ell</math>)</li> </ul>  |
| <b>DØ:</b><br>$2.3 \text{ fb}^{-1}$  | <ul style="list-style-type: none"> <li>• 2 identified leptons (e, <math>\mu</math>) + <math>\ell</math></li> <li>• <math>\mu\tau + \ell</math> and <math>\mu\tau + \tau</math> (<math>\tau</math> had decay)</li> <li>• "low"-pT vs "high"-pT search</li> </ul> |

Background is reduced with several set of kinematical cuts: inv-mass cut, lepton (track) p<sub>T</sub> cut,  $E_T$ , M<sub>T</sub>,  $\Delta\Phi$  between leptons, number of jets...

diboson (WW,WZ)  
Drell-Yan  $W \rightarrow l\nu$ ,  $t\bar{t}$

# SUSY in Trileptons (cont'd)



Control regions in MET vs  $M_{\ell\ell}$  phase-space

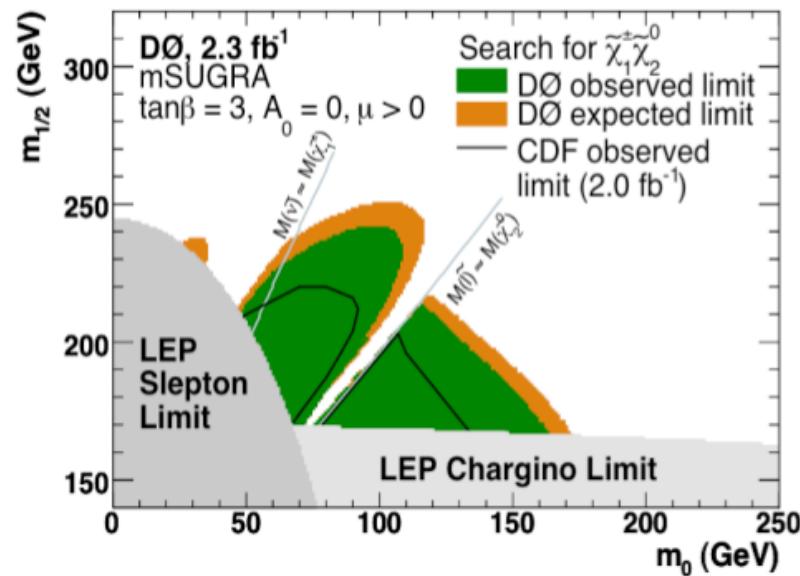
- Signal region is investigated only after validating backgrounds in control regions (a blind analysis)

- Good agreement with SM background

DØ $\int Ldt = 2.3 \text{ fb}^{-1}$		CDF $\int Ldt = 2.0 \text{ fb}^{-1}$	
	Background Data		Background Data
low $p_T$	$5.4 \pm 0.6$	9	Trilepton $0.88 \pm 0.14$
high $p_T$	$3.3 \pm 0.4$	4	Lepton+track $5.5 \pm 1.1$

Data compatible with SM  
Set limits in the mSUGRA model

Benchmark scenario:  
 $A^0=0, \tan\beta=3, \mu > 0$



# Sneutrinos in $e+\mu/\tau$ final states

**R-parity:**  $R_P = (-1)^{2S}(-1)^{3(B-L)}$

- R-parity violation: automatic generation of neutrino masses and mixing... single sparticle can be produced

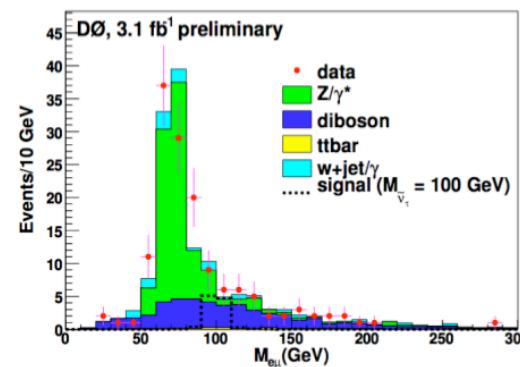
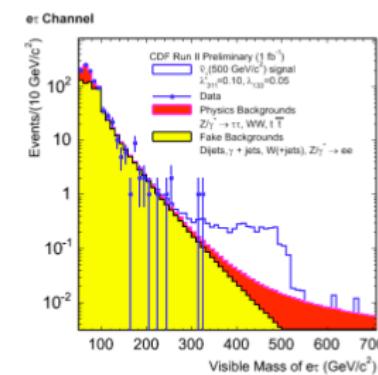
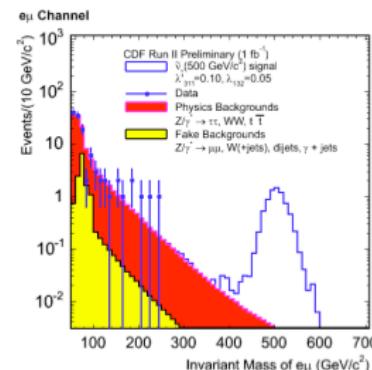
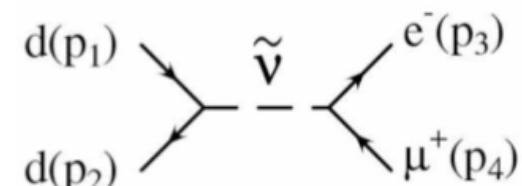
**Very clean signature:**

- 2 hard isolated leptons
- typical signal acceptance: 5 to 15%

## Search Strategies

- CDF: •  $1.0 \text{ fb}^{-1}$   
• 3 channels:  $e\mu$ ;  $\mu\tau$ ;  $e\tau$

- DØ: •  $4.1 \text{ fb}^{-1}$   
• only one channel:  $e\mu$



DØ places limits on  $\lambda'_{311}$  for several values of  $\lambda_{321}$  depending on the stau mass.  
CDF places limits on the stau mass. Updated limits underway (using more accurate theo. predictions).

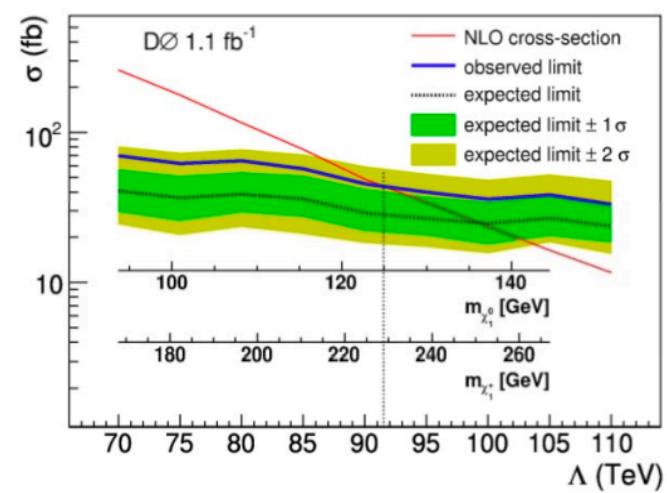
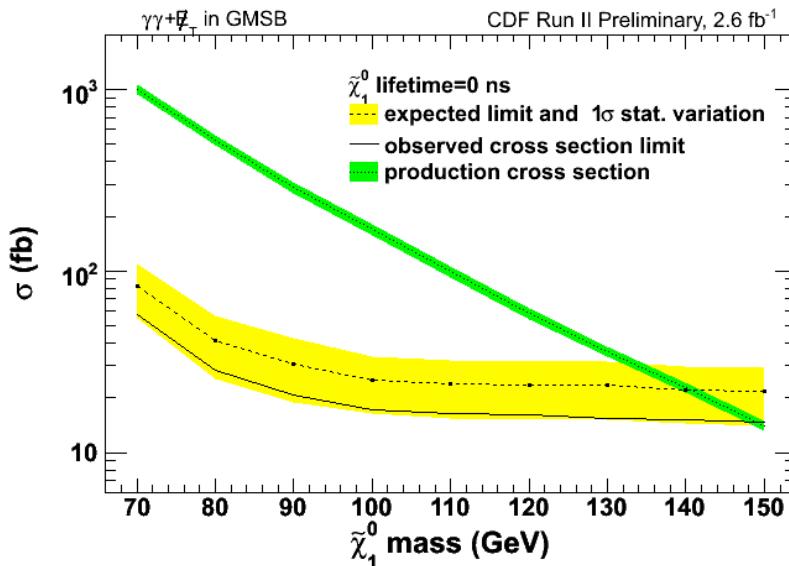
# GMSB SUSY

In gauge mediated SUSY breaking models, SUSY is broken in a hidden sector. The breaking is communicated to (s)quarks, (s)leptons and Higgs(ino) via gauge bosons and gaugino interactions.

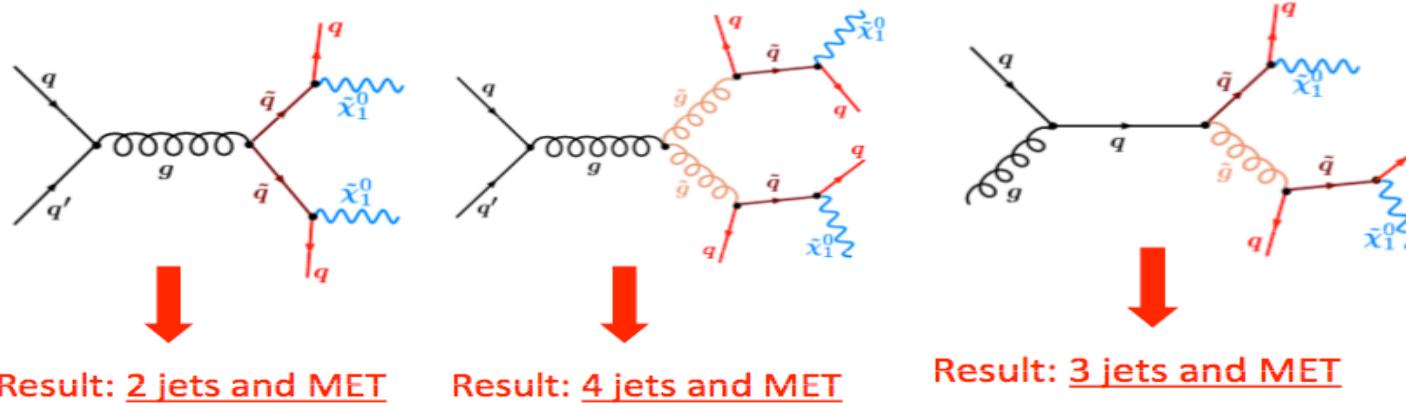
Special features:

- **gravitino is the LSP**
- **NLSP is a neutralino or a slepton**
- **NLSP can decay early enough to occur in the detector volume**
- **If NLSP = neutralino, one has:  $\tilde{\chi}_1^0 \rightarrow \tilde{G} \gamma$**

$$p\bar{p} \rightarrow (X \rightarrow) \tilde{\chi}_1^0 \tilde{\chi}_1^0 \rightarrow 2\gamma + \cancel{E}_T$$



# Squarks and gluinos: jets +MET

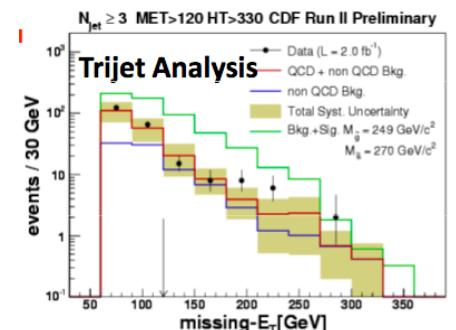


- Although the production is strong, the analyses are challenging due to QCD-mujet and W/Z+jet backgrounds
- Solution: break-down analyses in jet-multiplicity bins and optimize separately (using MET and HT  $\leftarrow$  Sum of jet  $E_T$ )

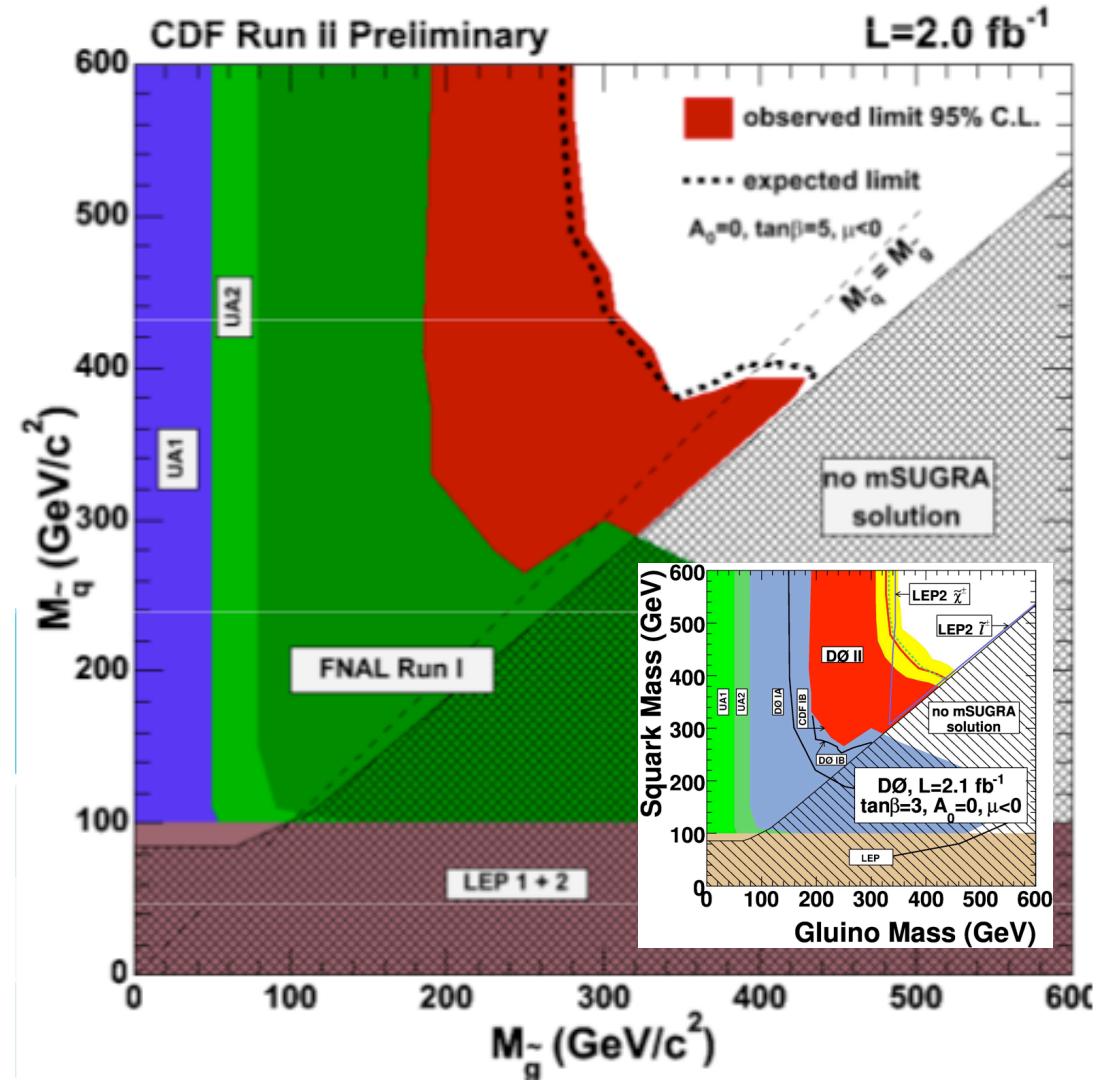
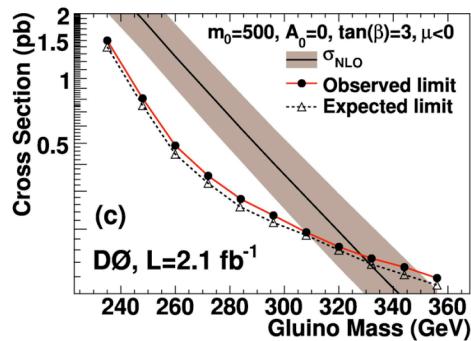
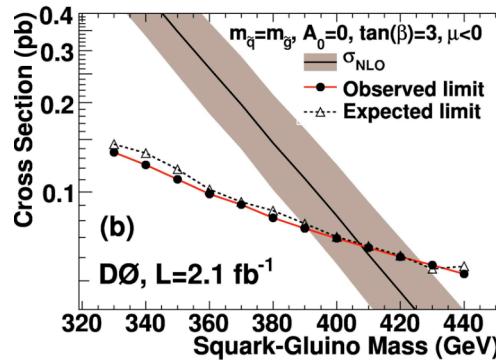
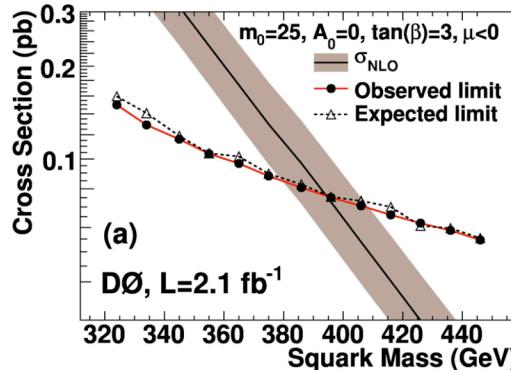
D0, PLB 660, 449 (2008),  $\mathcal{L}=2.1 \text{ fb}^{-1}$

CDF Run II Preliminary,  $\mathcal{L} = 2.0 \text{ fb}^{-1}$

Analysis	HT cut (GeV)	MET cut (GeV)	Jet Et (GeV)	Bckg.	DATA	Analysis	HT cut (GeV)	MET cut (GeV)	Jet Et (GeV)	Bckg.	DATA
Dijet	325	225	<b>35,35</b>	$11 \pm 1 +3/-2$	<b>11</b>	Dijet	330	180	<b>165,100</b>	$16 \pm 5$	<b>18</b>
Trijet	375	175	<b>35,35,35</b>	$11 \pm 1 +3/-2$	<b>9</b>	Trijet	330	120	<b>140,100,25</b>	$37 \pm 12$	<b>38</b>
4-jet	400	100	<b>35,35,35,20</b>	$18 \pm 1 +6/-3$	<b>20</b>	4-jet	280	90	<b>95,55,55,25</b>	$48 \pm 17$	<b>45</b>



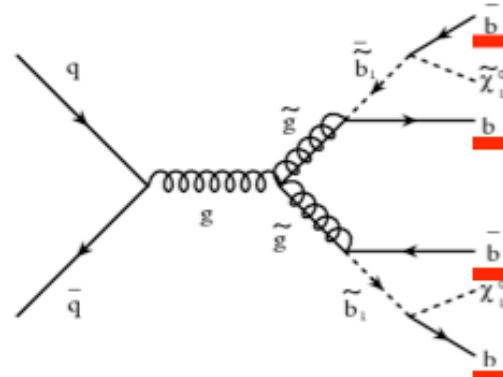
# SUSY in MET + jets





# Search for sbottom from gluino decay

If the sbottom is significantly lighter than the other squarks, the two body decay of gluino into bottom/sbottom is kinematically allowed



The analysis is optimized for 2 points in the SUSY parameter space:

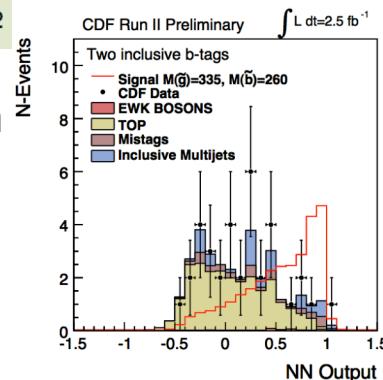
### Large $\Delta m$ between $\tilde{g}$ and $\tilde{b}$

$M(\tilde{g}) = 320 \text{ GeV}/c^2$ ,  $M(\tilde{b}) = 250 \text{ GeV}/c^2$ ,  $M(\tilde{\chi}) = 60 \text{ GeV}/c^2$

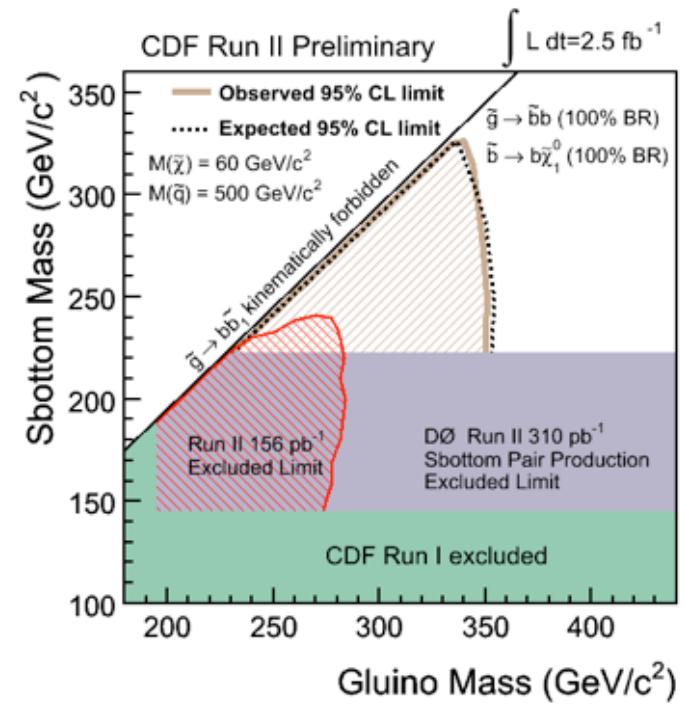
### Small $\Delta m$ between $\tilde{g}$ and $\tilde{b}$

$M(\tilde{g}) = 300 \text{ GeV}/c^2$ ,  $M(\tilde{b}) = 280 \text{ GeV}/c^2$ ,  $M(\tilde{\chi}) = 60 \text{ GeV}/c^2$

In the signal region a further optimization is performed using a neural network output



The sbottom decays into a bottom and LSP, giving rise to a final state with 4 b-jets and missing energy



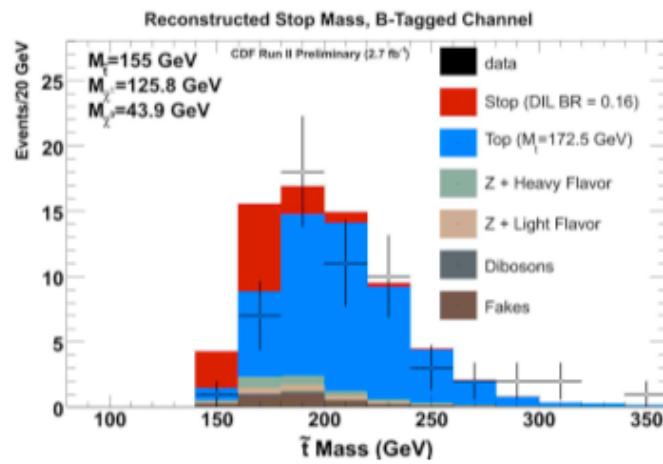
# Stop Searches

If stop light enough,  $m[\tilde{t}] < m[t]$ , several interesting decays, depending on the sparticles spectrum:

1.  $\tilde{t} \rightarrow b \tilde{\chi}_1^+ \rightarrow b l \nu \tilde{\chi}_1^0$  ( $m_{\tilde{\chi}_1^+} < m_{\tilde{t}}$ )
2.  $\tilde{t} \rightarrow b \tilde{\nu} l$  ( $m_{\tilde{\chi}_1^+} > m_{\tilde{t}}$ )
3.  $\tilde{t} \rightarrow c \tilde{\chi}_1^0$

- I. CDF 2.7 fb<sup>-1</sup>:** dileptons (e/μ) with one isolated lepton,  $\cancel{E}_T$ , high  $p_T$  jets, b-tagging. reconstruct the stop mass with a kinematic fit.

$$\tilde{t}_1 \bar{\tilde{t}}_1 \rightarrow b b l l' \nu \bar{\nu} \tilde{\chi}_1^0 \tilde{\chi}_1^0$$

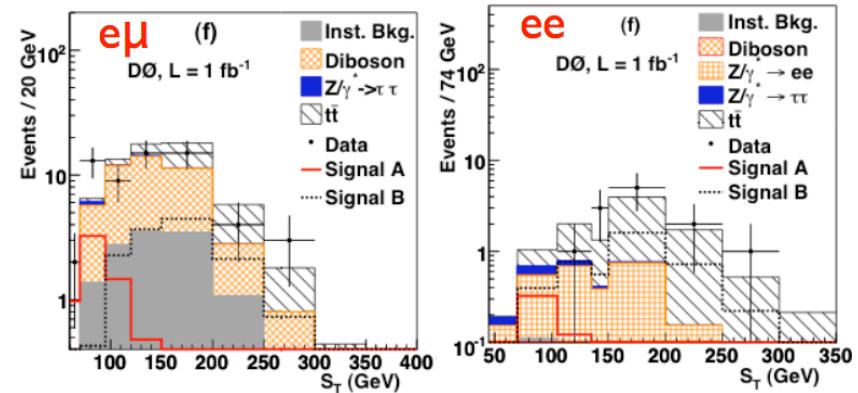


## 2. DØ 1.0 fb<sup>-1</sup>: ee, eμ.

require hight  $p_T$  isolated leptons,  $\cancel{E}_T$ , use kinematics and b-tagging (for ee) to disentangle signal from background.

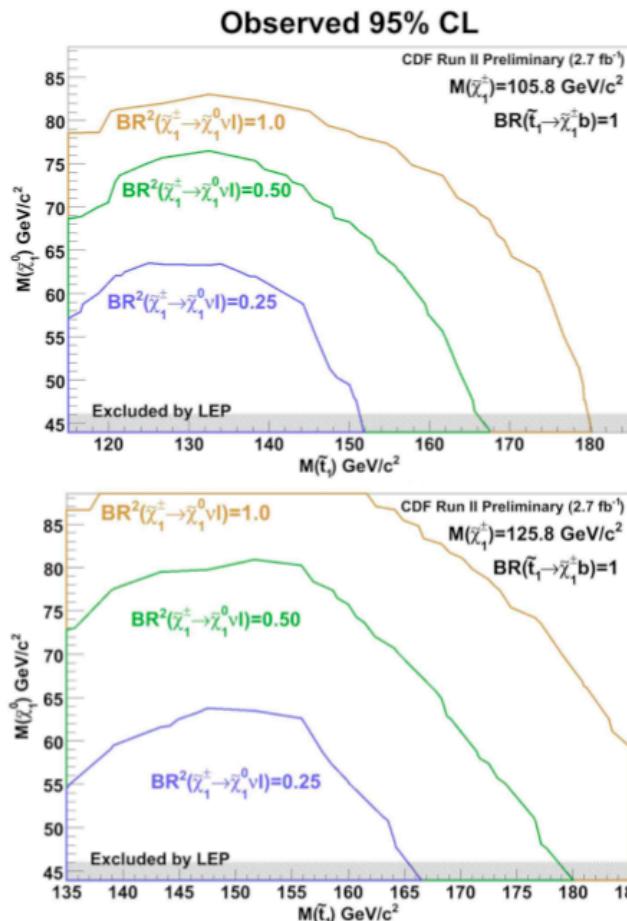
Signal efficiency ranges from 0.1 to 10% depending on  $\Delta m = m_{\tilde{t}_1} - m_{\tilde{\nu}}$

$$\tilde{t}_1 \bar{\tilde{t}}_1 \rightarrow b b l l' \bar{\nu} \bar{\nu}$$

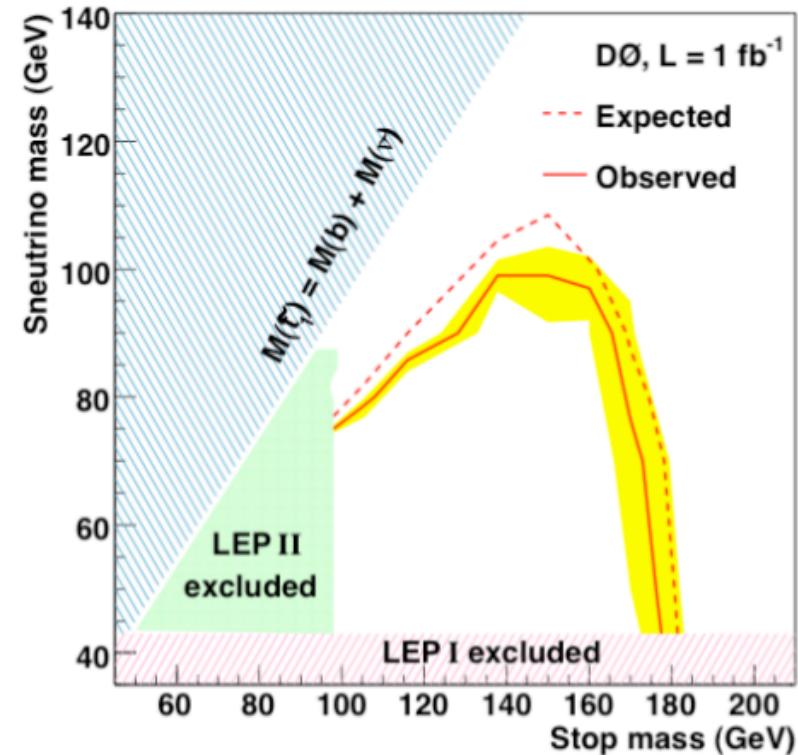


# Stop Searches (cont'd)

$$\tilde{t}_1 \bar{\tilde{t}}_1 \rightarrow b b l l' \nu \bar{\nu} \tilde{\chi}_1^0 \tilde{\chi}_1^0$$

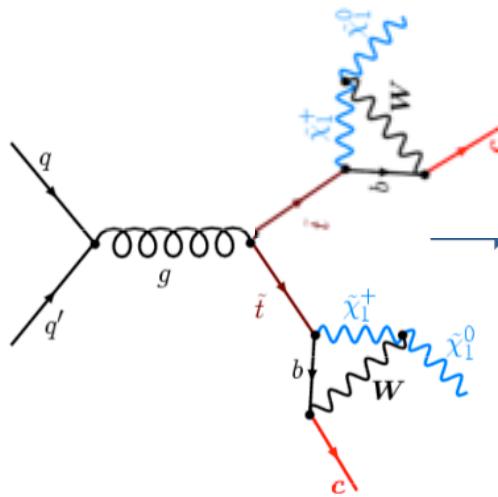


$$\tilde{t}_1 \bar{\tilde{t}}_1 \rightarrow b b l l' \tilde{\nu} \bar{\tilde{\nu}}$$





# Stop searches (cont'd)



**Stops to charm**

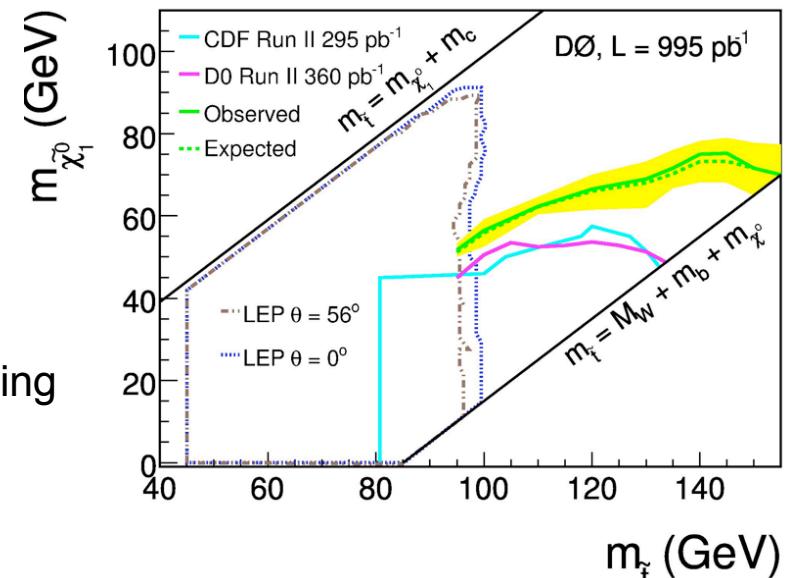
$$\tilde{t} \rightarrow c \tilde{\chi}_1^0$$

Exactly 2 jets ( $E_T > 15$  GeV)  
 MET  $> 40$  GeV

Jets are tagged using a NN tagging tool

Final selection is optimized for  
 Stop and neutralino masses

$m_{\tilde{t}}$	$H_T$	$S$	Observed	Predicted
95 – 130	$> 100$	$< 260$	83	$85.3 \pm 1.8^{+12.8}_{-13.0}$
135 – 145	$> 140$	$< 300$	57	$59.0 \pm 1.6^{+8.5}_{-8.8}$
150 – 160	$> 140$	$< 320$	66	$66.6 \pm 1.1^{+9.6}_{-10.0}$



**Exclusion: stop mass  $< 149$  GeV/c $^2$  for  
 neutralino mass of 63 GeV/c $^2$**

# Searches for CHAMPS

Charge Massive Stable Particles (CHAMPS) are predicted by several extension of the SM. They could be stau and/or charginos (GMSB, AMSM) or stop.

CHAMPS may appear as “slow” moving highly ionizing and highly penetrating particles (muons).

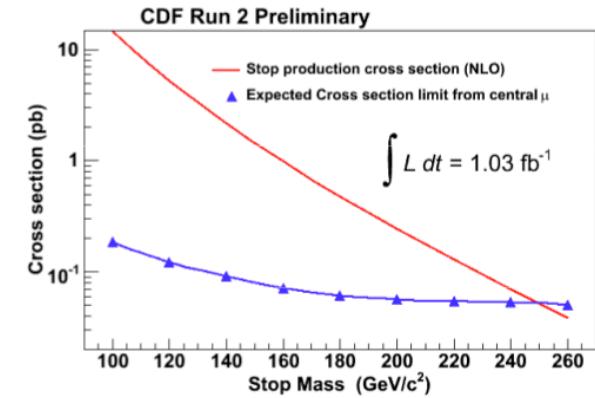
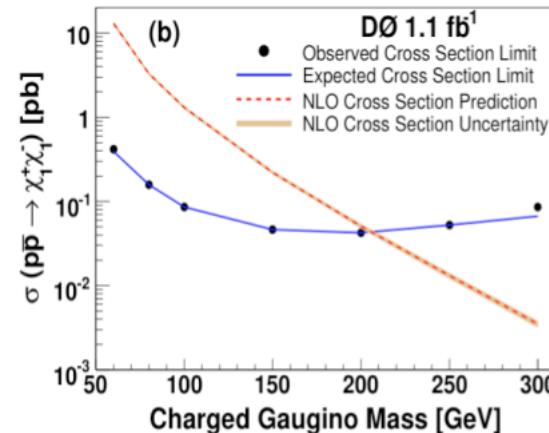
Striking signature: isolated high PT muons, with possible calorimeter deposition

- D0 ( $1.1\text{fb}^{-1}$ ) uses timing in the muon system to measure the speed while the dimuon mass provides discrimination

- CDF ( $1.03\text{fb}^{-1}$ ) uses the TOF detector to measure the mass and sets a limit on the stop mass - long TOF and large dE/dx

## Limits: (D0)

- $\tilde{\tau}$ : no sensitivity
- $\tilde{\chi}_1^+$ ,  $\tilde{h}$ -like  
 $m_{\tilde{\chi}_1^+} > 171 \text{ GeV}$
- $\tilde{\chi}_1^+$ , gaugino-like  
 $m_{\tilde{\chi}_1^+} > 206 \text{ GeV}$



## Limits: (CDF)

$$m_{\tilde{t}} > 249 \text{ GeV}$$

# Conclusions

Many exciting results are continuously produced at the Tevatron!

The search for physics beyond the SM is carried on through a careful analysis of various final states using model driven as well as signature based approaches.

A bump can be around the corner before the LHC turns on....



# References

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- <http://www-cdf.fnal.gov/physics/exotic/exotic.html>
- <http://www-d0.fnal.gov/Run2Physics/WWW/results/np.htm>

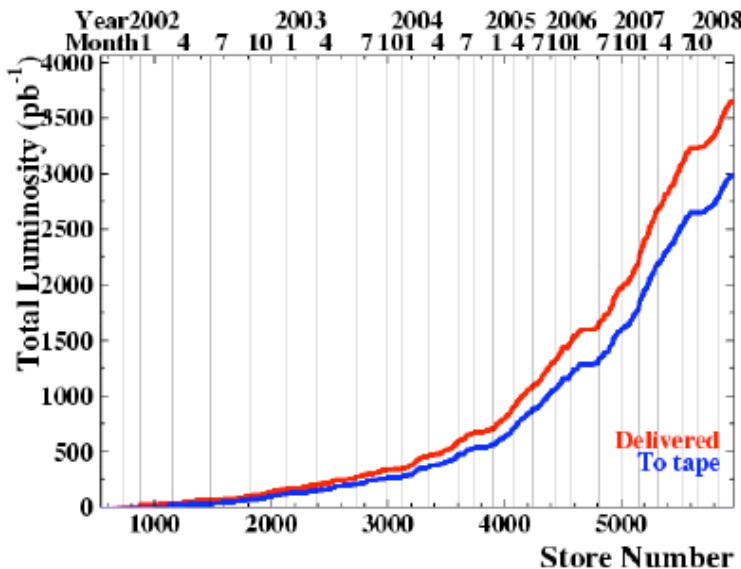
# Backup

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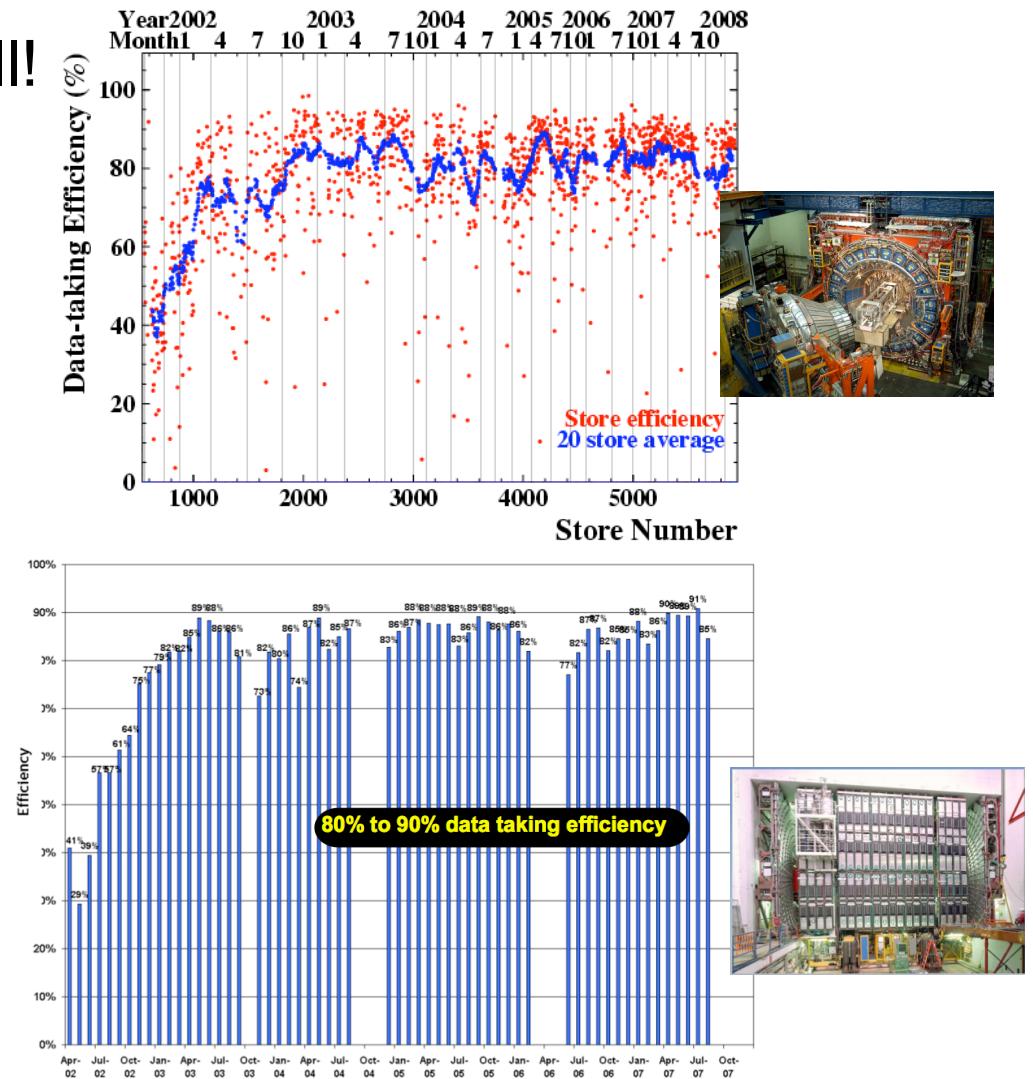
# TeVatron Status

The TeVatron is doing very well!

## Luminosity Profile



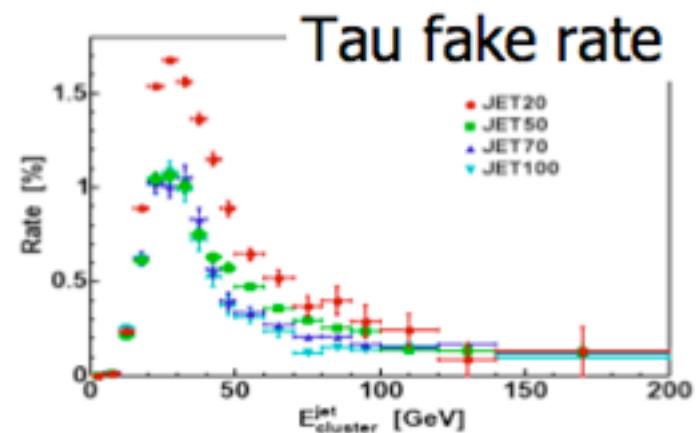
Delivered Lumi. > 3.6  $\text{fb}^{-1}$   
Good for analysis ~ 3.  $\text{fb}^{-1}$



# Lepton Efficiencies

- Compare “typical” high-pt ( $>20$  GeV) isolated lepton efficiency and fake rates

Lepton	Efficiency	Fake Rate
electron	~80%	~0.01%
muon	~85%	~0.01%
tau (box cuts)	~45%	~1-0.1%
tau (neural net)	~80%	~5-1%



# Jets and Heavy Flavor

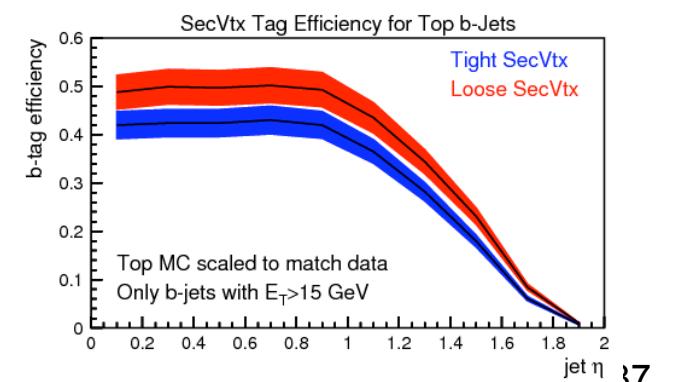
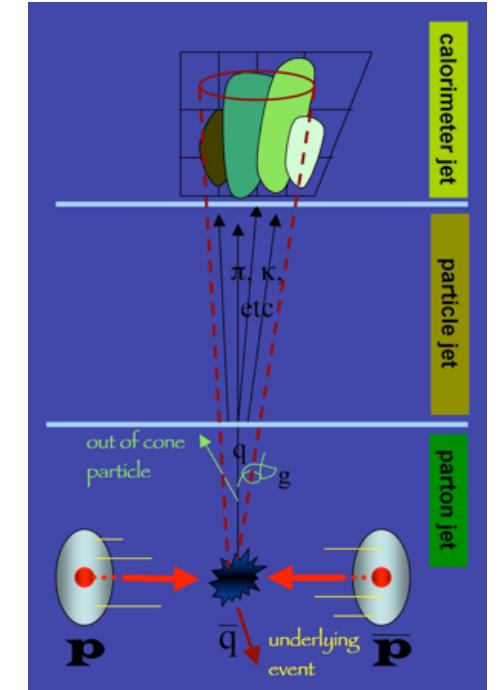
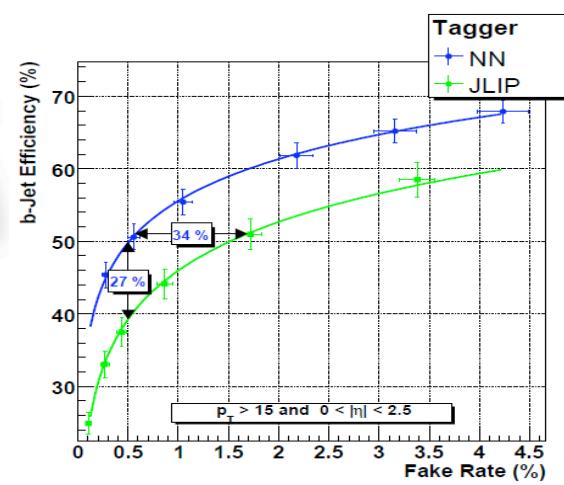
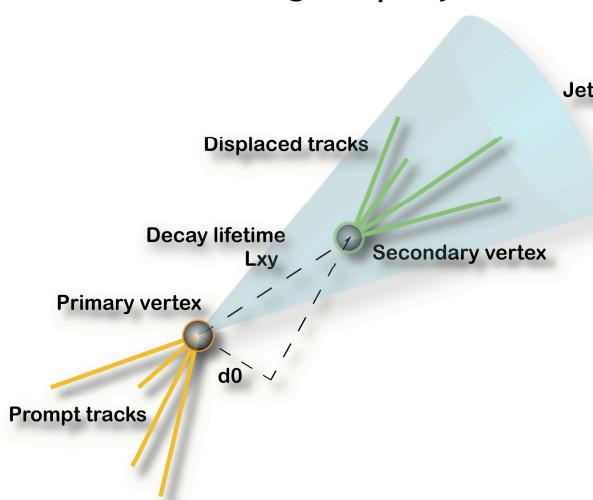
Hadronic jets are reconstructed using several algorithms:

Cone, Midpoint, KT etc..

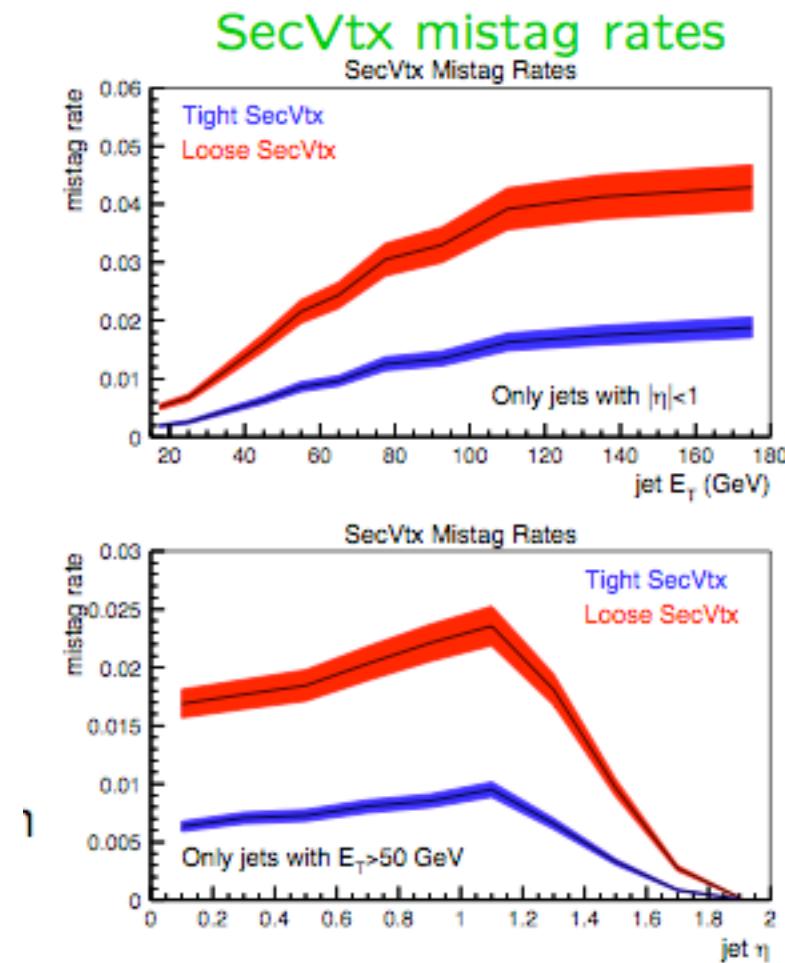
Measured jet energies are corrected to scale them back to the final state particle level jet. Additionally there are corrections to associate the measured jet energy to the parent parton energy, so that direct comparison to the theory can be made. Currently the jet energy scale is the major source of uncertainty in the measurement of the top quark mass and inclusive jet cross section

B-jet identification is implemented via:

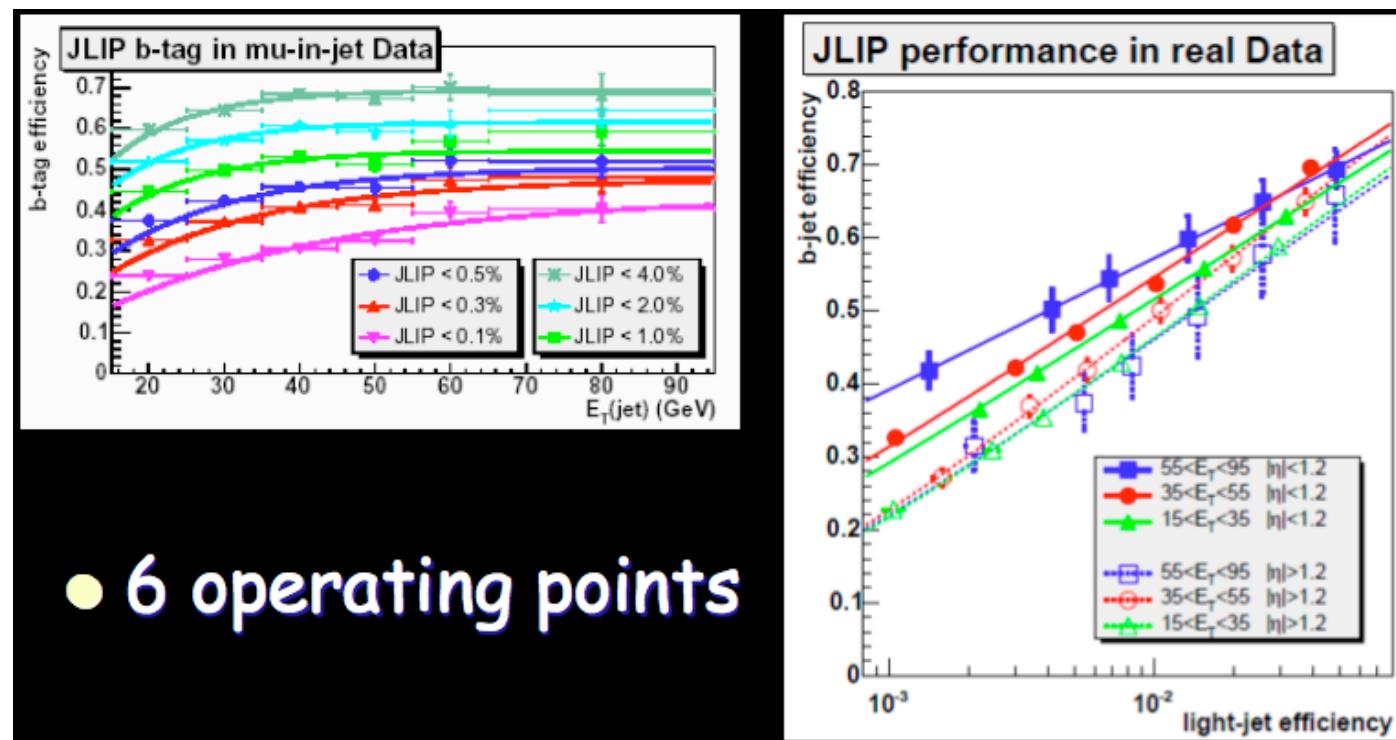
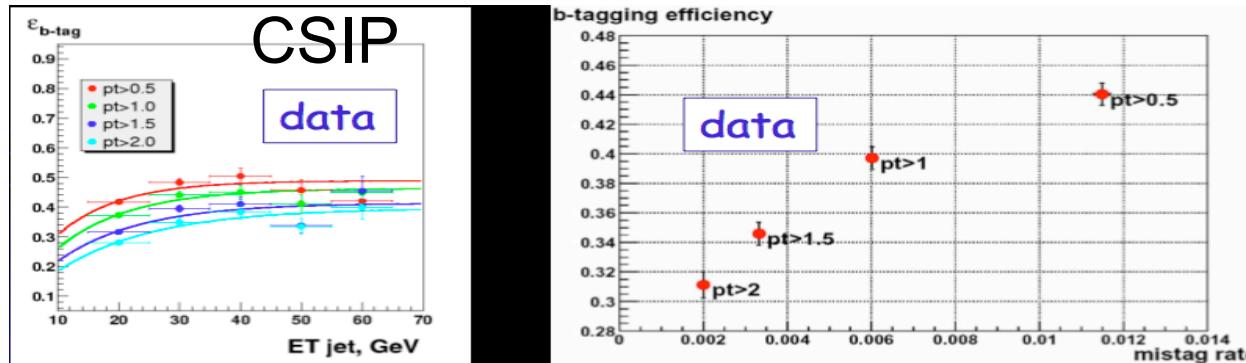
- displaced vertices with  $L_{xy}/\sigma$  cut (CDF)
- Vertex mass separation (CDF)
- combining vertex properties and displaced track info with NN (D0)
  - Tag to  $\eta$  beyond 2



# Btagging Mistag Rate (CDF)

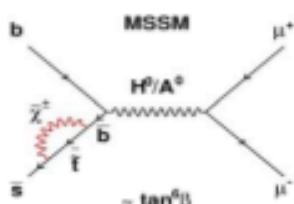


# D0 btagging



# $B_s \rightarrow \mu\mu$

Sensitive to new physics: if no observation, it can strongly constraint SUSY models



MSSM  
 $H^0/A^0$   
 $\sim \tan^6 \beta$   
 SM prediction:  
 $BR = 3.42 \times 10^{-9}$   
 SUSY enhancement  
 $\sim (\tan \beta)^6$

- Data sample dominated by random combinatorial background
- Extract signal with Neural Net based discriminant

$B_s$  and  $B_d$  considered separately:

$B_s \rightarrow \mu\mu$  3 observed events ( $3.6 \pm 0.3$  exp.bkg.)

$B_d \rightarrow \mu\mu$  6 observed events ( $4.3 \pm 0.3$  exp.bkg.)

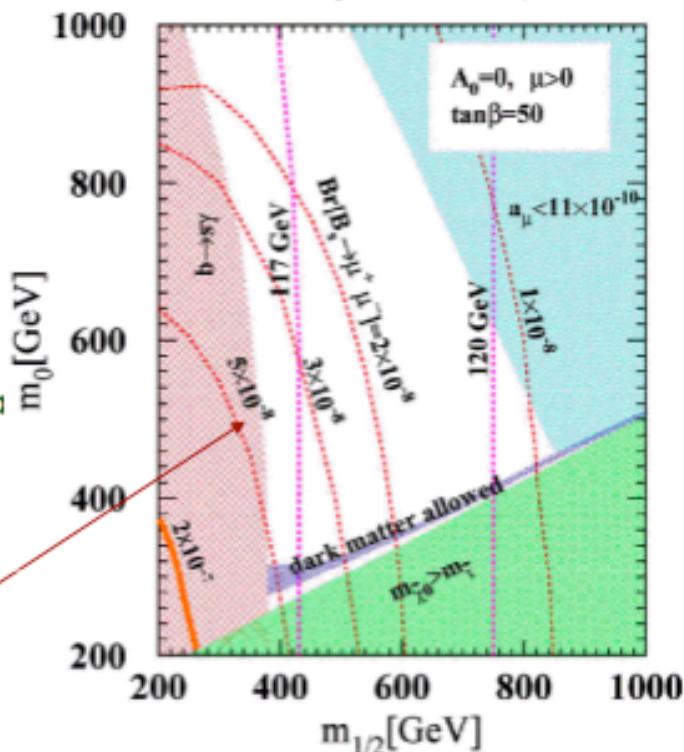
No significant excess  $\rightarrow$  exclusion limit

$$Br(B_s \rightarrow \mu\mu) < 5.8 \times 10^{-8} @ 95\% CL$$

$$Br(B_d \rightarrow \mu\mu) < 1.8 \times 10^{-8} @ 95\% CL$$

Comb CDF/D0

mSUGRA at  $\tan \beta = 50$   
 Arnowitt, Dutta, et al., PLB 538 (2002) 121



$$Br(B_s \rightarrow \mu\mu) < 1.5 \times 10^{-7} @ 95\% CL$$

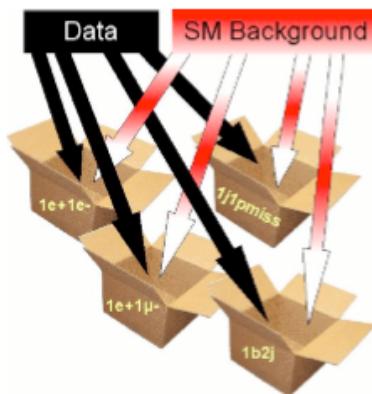
[hep-ex/0508058](https://arxiv.org/abs/hep-ex/0508058)

# Global Searches at CDF

The goal is to perform a model-independent global search of high  $P_T$  data:

- study bulk features of high  $P_T$  data;
- search for resonances invariant mass distributions
- search for significant excesses at high sum- $p_T$

Physics objects are categorized and events selected and partitioned into  $\sim 400$  exclusive final states

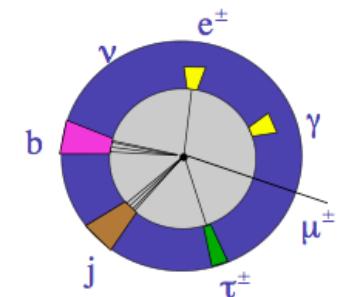


The whole  
high  $P_T$  region  
is monitored at  
once

Pythia and MadEvent are used to implement the SM theoretical prediction (CdfSim emulates the detector response)

Many correction factors are used to obtain the *true* SM predictions (shouldn't a global search work globally?)  
theory k-factors etc  
experimental efficiencies and Scale Factors, fake rates etc

Currently observed discrepancies are explained in terms of incorrect MC modeling



# Global Searches at D0

DØ also uses common MC

PYTHIA and ALPGEN

Multijets background from data

Apply common collaboration-wide scale factors

Can be bin-by-bin or several parameter functions

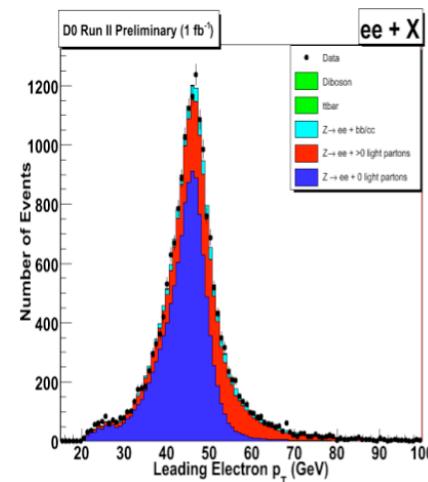
Use phase space dominated by SM processes

Then fit for normalization factors

Trigger efficiencies, k-factors, etc

7 inclusive final states

Exclude high- $p_T$  tails



Search limited to final states with leptons

3 basic modeling issues

$\eta$ -dependent trigger efficiency in  $\mu + \text{jets} + \text{MET}$

Muon resolution

in  $\mu\mu + \text{MET}$

Jets misidentified as photons in  $\gamma$  states

All of the given discrepancies point to modeling difficulties

